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THE FLEET AND AVIATION.*

By REAR ADMIRAL HILARY P. JONES, U. S. Navy.

Mr. Chairman and Members of the American Society of Naval Engineers:

I deem it a great honor that I have been invited to address such an assemblage as this, composed as it is of men eminent in the scientific and mechanical world. I am fully conscious that I am merely a layman and as such I must ask your forbearance if I seem to trespass on ground that is essentially your own, and hope you will not think such trespass presumptuous in me. I will say at the start that I do not presume to speak as one having intimate technical knowledge of the scientific details of the design and construction of aircraft, but I have had the privilege recently of listening to the expert testimony

* Address delivered at the Annual Dinner of the AMERICAN SOCIETY OF NAVAL ENGINEERS, March 14, 1925, at Washington, D. C.

of many men eminent in both, and from them I have learned some fundamental truths that have enabled me to evaluate the relationship that should pertain between the sea and air elements of the National Defense. It may be that in following the lines of thought of the layman in arriving at his final conclusions, the scientist will have a clearer comprehension of the method of reasoning that will best reach the average mind.

I have chosen as my subject tonight "The Fleet and Aviation."

It is a fundamental truth that the power to keep open the lines of communication along which its commerce is carried is necessary to the commercial life and prosperity of a nation that is engaged in trade outside of its own borders. At the present time, and as far in the future as human vision can reach, such lines of communication are and will be on the surface of the sea. Therefore, sea power will be necessary to keep them open.

The three most important elements of sea power are:

(*a*) A powerful and efficient navy.

(*b*) Properly equipped and defended bases for the use of the fleet in areas where hostilities may occur.

(*c*) A merchant marine adequate to the task of carrying on the nation's trade and of supplying its fleet in time of war.

The mission of the Navy is to support the national policies and guard the national interests in all parts of the world.

The Navy of the United States should be maintained in sufficient strength to support its policies and its commerce, and to guard its continental and overseas territories and possessions.

The fleet, which includes all types of combatant and necessary auxiliary units, is the ultimate force employed in the exercise of sea power.

A properly constituted fleet consists of battleships, battle cruisers, cruisers, aircraft carriers, aircraft, destroyers, submarines, minelayers and auxiliaries.

The battleship is the element of ultimate force in the fleet, and all other elements are contributory to the fulfillment of its function as the final arbiter in sea warfare.

The other elements have their important, and at times indispensable, functions.

With the invention and development of offensive weapons have always come the counter invention and development of defensive means and methods, so that in the end a fair balance is struck between them. The history of the gun and armor, and of the torpedo and interior subdivision, merely repeats the process by which offense always begets defense.

Aviation has introduced a new and highly important factor in warfare, both on the land and on the sea. While it was utilized on an enormous scale and with effectiveness in land operations during the World War, it did not seriously influence sea operations. However, its influence on naval warfare undoubtedly will increase in the future. Therefore, it may be said that aviation has taken its place as an important element of the fleet in its exercise of sea power and can not be separated from it.

I will not attempt, in the short time allotted, to outline to you the strategical and tactical functions of the various types of ships and aircraft necessary to a well coordinated fleet. Suffice it to say that it is necessary so to coordinate the operations of all the types that harmonious working together of the whole will result. The purpose of a Naval Air Service is to contribute to the success of the fleet in battle. Peace time organization must therefore be built with that object and no other in view.

From earliest times man has dreamed of flying. From da Vinci's rude Helicopter of 1500 A. D., the first real effort at dynamic flying, to our *PN-7* of 1924, is a long span. Within that span every century has had its dreamers of flying but fully four centuries passed before the dreams were realized.

Towards the end of the 19th century many inventors and writers were turning attention to aviation, and such pioneers

as Lilienthal, Maxim, Pilcher and others developed power machines of great ingenuity which contained some elements of success. Many of the principles of aerodynamics were worked out, but efficient motive machinery was lacking.

With the advent of the internal combustion engine came really practical attempts to navigate the air by a man-controlled heavier-than-air machine. The first that seemed to give real promise of success was that of Professor Langley made on the Potomac in 1903. The causes of his failure need not be touched on further than to say that they were due to accidents rather than to fundamental errors in design. At this time many minds, both in this country and abroad, were working on the problems of flying. Among them were the Wright brothers, who may be truly regarded as the real pioneers in the art as it is now known. The Wrights attacked the problem in a practical way with gliders, beginning in 1900. From these experiments logically grew the application of power to drive the machine through the air and gain flotation by speed of motion, and at the end of 1903 they successfully flew the first man-carrying power-driven airplane. Their first public demonstration was given by the Wrights at Fort Myer in 1908, since which time the progress of the art has been steady, rapid and convincing. When the fundamental aerodynamical problems had been solved, the development of the motive machinery became the important function of the aeronautical engineer.

When the Wrights' plane rose in the air from its rude catapult and circled the field, I happened to be standing near Lieutenant Sweet of the Navy, who had been detailed by the Bureau of Equipment to observe these tests. As soon as he had caught his breath from the wonder of it, Lieutenant Sweet remarked, "The Navy must have that; it will be most important for us." From that time it was given to individual naval officers to look into the future and visualize somewhat the potential value of this new element in the national defense forces. Their hopes and prophecies were boundless, but for those who were charged with the responsibility of the protection of the national inter-

ests, a certain conservatism was proper until this new art had really proved itself. There were times in the early stages when such conservatism seemed unreasonable to the enthusiasts and discouragement was their portion. Foreign nations were more prompt to take up aviation seriously, and American pioneers saw an art which they justly felt was their own more accepted abroad than by their own people. But, fortunately, the enthusiasts would not give up and as others joined them in ever greater numbers, conservatism eased off the brakes and aviation began to take its place in the armed forces of the country as an important element. Beginning in 1914 the General Board of the Navy has consistently, every year since, recommended liberal appropriations for aviation building programs.

During the period of development, from 1908 to the present time, the Navy and naval officers have rendered important and valuable service, particularly in the design, development and operation of seaplanes. A few outstanding accomplishments will give some idea of what the Navy has done.

In 1909, the first naval officer made a flight in an airplane. In 1910, under the auspices of the Navy Department, Ely flew from special deck of the U. S. S. *Birmingham* in a land plane. In 1911, Curtiss and a naval officer made first passenger carrying flight in a seaplane. In this year radio experiments for communication from airplanes were started at Annapolis. Under the auspices of the Navy Department, Ely landed on a platform over the quarter deck of the U. S. S. *Pennsylvania* and flew back to the beach, using cross lines with sand bags as arresting gear on the ship. The same general system of arresting gear, but very much developed, is now used on the *Langley*. Model Basin tests were started at the Washington Navy Yard. In 1912, under the auspices of the Navy Department, the boat form of plane was developed at San Diego. In the same year, a catapult for ship use was designed at the Naval Gun Factory and successful shots with the hydro and boat form types of planes were made with a naval officer as pilot. Design of an 8 foot by 8 foot wind tunnel was started at the Model Basin,

Washington Navy Yard. In 1913, the wind tunnel at Massachusetts Institute of Technology was built and the first course in Aeronautical Engineering started under the supervision of a naval officer. At Vera Cruz, seaplanes from the U. S. S. *Mississippi* conducted patrol and scouting flights inland on 43 days and also searched the entrance channel for mines. In 1915, the National Advisory Committee for Aeronautics was organized with a naval officer as its first Secretary. The first Navy designed seaplane was authorized to be built at the Model Basin. The first catapult flight from ship under way was made with Captain Mustin as pilot. In 1919, the first trans-Atlantic flight was made by the *NC-4* flying boat, belonging to the Navy. In 1920, a Navy F-5-L squadron made a 13,000-mile cruise with the Atlantic Fleet through the West Indies. In 1921, 12 Navy F-5-L planes, attached to the Pacific Fleet, made a flight from San Diego to Panama. In 1922, a catapult was first installed on a battleship and operated in fleet maneuvers. In 1923, a squadron of 9 Navy F-5-L planes flew from Hampton Roads to Panama, took part in scouting operations and fleet maneuvers and returned to Hampton Roads. The Navy established the world's speed record for seaplanes of 177 miles per hour and the world's speed record for airplanes of 244 miles per hour.

The first wind tunnel of modern type mentioned above was designed by Naval Constructor D. W. Taylor at the Experimental Model Basin in 1912, in order to find the engineering basis for the design of naval aircraft. It is of interest to observe Taylor's foresight and enterprise in providing the scientific apparatus for the analysis and improvement of plane design. This tunnel was, and remained for several years after, the largest and most powerful in the world. With the Tunnel and Model Basin many problems were solved and valuable data obtained in the development of hulls and floats for seaplanes.

In the development of radio communication from aircraft, the Navy has, undoubtedly, taken a leading part and the accomplishments of the Bureaus of Engineering and Aeronautics in this essential to the usefulness of aircraft to the fleet have been

most valuable. The problems to be solved have been difficult, but the results obtained have fully repaid the expenditures of brains and money involved. In all of the investigations and experiments, the cooperation of the Army has been most valuable and helpful, and the Navy readily pays its full tribute to the sister service in this work. In view of the fact that each pound carried in an airplane must be considered, the development of light weight radio sets for long distance communication has been one of the most important considerations and the accomplishment in this direction has been worthy of particular note. As stated above, the Navy began tests with radio for aircraft as early as 1911, from which time investigation and development work have been carried on steadily until now, when such accomplishments as the following have been reached:

Bellevue Laboratory, near Washington, maintained communication with the *Shenandoah* near San Diego, a distance of about 2500 miles, for a period of one-half hour, despite unfavorable conditions of static and interference. The *Shenandoah,* at her mooring mast at San Diego, transmitted and was heard by the U. S. S. *Canopus,* about 4400 miles away. An operator in New Zealand reported reception of signals transmitted from the *Shenandoah,* and copied an entire message at a distance of 6180 miles.

Two ship planes from the *West Virginia* were able to spot the long range battle practice of the *West Virginia* and the *Colorado,* maintaining excellent two-way communication, and the spots from the planes were received for all salvos.

The tests of new airplane sets indicate that radio installation will permit reliable two-way radio communication between plane and ship up to 400 miles.

The Bureau of Aeronautics has accomplished an enormous amount of work in the development, construction and installation of planes and catapults on board ship. There are now installed on battleships and light cruisers in the Fleet a total of 29 efficient catapults, and 48 planes that are being operated from the catapults. In addition, there are 82 planes organized

in squadrons and are operating with the Fleet from shore bases, the *Langley* and tenders. All of these planes are of the latest approved, tested and accepted designs. I believe that it is not beyond the bounds of truth to say that aviation in our Navy now stands well ahead of the rest of the naval world. I do not make this statement in any boastful spirit nor without warrant, as it is the testimony of many eminent experts and builders that such is the case.

Much criticism of a recent Board, of which I was a member, has been uttered to the effect that we stressed too much what aircraft can not do and had too little to say as to what they can do. It seems to me a fundamental requisite to determine the extreme limit of performance possible to the instrument under investigation and then study its capabilities within that limit. To indulge in dreams of accomplishment beyond possibility of performance, with materials known to man, would be rank waste of time, certainly when one is considering policies for the national defense. The testimony of scientists and engineers whose researches in aerodynamics and motor mechanics have been most profound and whose data are recognized throughout the world as beyond question, shows conclusively that there are inherent limitations to the performance of heavier-than-air craft. It must be borne in mind always that flotation in a medium lighter than the body to be floated requires the maintenance of a certain speed through the medium which, in turn, requires a driving force to produce that speed. The automobile or the railroad train can stand still on the land and the ship on the water, but the airplane can not stand still in the air; it must move at high speed or it will come to earth, thus imposing an inescapable limitation on size and weight.

In considering the characteristics of types of naval units for operations in distant oversea areas and in the battle itself, the outstanding requirements are endurance and offensive power against other naval units; that is, the ability to exert force where needed. In the case of aircraft, the first, that is, endurance, depends on the weight of fuel, lubricating oil and

other necessary stores carried, relative to expenditure per hour at economical cruising speed. The second, that is, military efficiency in offensive and defensive operations, depends upon the military load carried. These two constitute the disposable weights that may be carried in a plane and are interchangeable. That is, the greater the weight that must be assigned to one element to accomplish the object, the less weight there is available for the other. Very heavy military loads can be carried only a comparatively short distance from the base of operations; distant overseas operations can be carried on only with full weight of fuel and practically no military loads. It may be mentioned here in connection with weights of military loads, particularly in regard to bombs, that doubling the weight of the explosive does not double the effect—it adds only 40 per cent. In other words, a 4000-pound bomb has only .4 more effect than a 2000-pound bomb in under water explosion, instead of 100 per cent as generally supposed.

There is a definite limit beyond which the airplane can not be developed to do any work at all because it can not get into the air. Well inside of this limit, there is a point where the performance begins to fall off rapidly, due to the fact that the ratio of the disposable load to the gross weight of the plane decreases until the point is reached when the disposable load becomes zero. Eminent authorities differ as to the point beyond which it is useless to increase the size of a plane but, accepting even the most optimistic of them, this point is far short of what is required for service to distant overseas areas. In other words, the performance of airplanes is limited to comparatively short distances from their bases of operations. It is the general consensus of opinion that thirty per cent increase over present performance is the best that can be hoped for within an indefinite time. To accomplish such increase, the attention of aeronautical engineers, designers and builders is now engaged on engine development primarily, as it is recognized that greater reliability of operation, lightness and economy in fuel consumption are the prime requisites of increased performance.

For military and naval operations special types are designed to accomplish particular tactical and strategical missions, such as fighting, bombing, torpedo, scouting, observation, spotting, etc.

The following are general characteristics essential in the design and development of the various types:

Fighting plane—high speed, offensive armament, great maneuverability, rapid climbing, great ceiling, etc.

Bombing plane—military load capacity and defensive armament, combined with as great endurance, maneuverability, ceiling, communication facilities, etc., as may be obtained.

Torpedo plane—same.

Scouting plane—great endurance (fuel, stores, personnel accommodations, etc.) defensive armament, long distance communication facilities combined with as great maneuverability, ceiling, etc., as may be obtained.

Observation plane—endurance, communication facilities, defensive armament, clear observation facilities, maneuverability, ceiling, etc.

Spotting plane—same.

The bombing, torpedo and scouting planes may be combined in one general type as the free load weights may be assigned to bombs or torpedoes for operations against armored ships, or fuel, stores, personnel, etc., for cruising endurance in long distance scouting.

Heavy duty planes such as bombing, torpedo, etc., although equipped with defensive armaments are peculiarly vulnerable to attack by fighting planes and anti-aircraft guns afloat and ashore, due to their comparatively low speed and limited ceiling when heavily loaded.

It is generally recognized that the operations of heavy bombers and torpedo planes must be carried on in comparative freedom from active hostile opposition in order to assure a reasonable degree of success in attack. This makes it imperative that the air be practically cleared of enemy fighting planes and that enemy anti-aircraft artillery be neutralized by counter-

operations of fighting planes or other means. Claim is made that anti-aircraft artillery may be neutralized by attacking from a ceiling outside of range of such artillery, but this claim is doubtful in view of the steadily increasing range of the guns and the limitation of ceiling imposed by weight of efficient offensive missiles. The torpedo plane must come close to the surface to discharge torpedoes and, therefore, can not find protection in ceiling. These considerations inevitably lead to the conclusion that the radius of the bombing and torpedo planes is limited to that of the accompanying fighting planes, unless forced to take long chances in more distant operations. In the latter case, the weight of bombs or torpedoes carried will be limited due to greater weight of fuel required to reach the attack. When the one, or at most two, bombs are dropped, the plane must return to its base as no reserve is available within itself.

From the foregoing, it is manifest that for distant oversea operations it is necessary that the planes be transported to the area of such operation in carriers or tenders. In other words, in surface ships. The airplane carrier is extremely vulnerable and must be protected not only by her own aircraft and guns against hostile aircraft and guns but, in the last analysis, by other surface ships, as she is vulnerable to underwater attack in the same manner and to the same degree as other surface ships; she is vulnerable to gun attack in the same manner and to a much greater degree than battleships and cruisers with protective armor.

The capacity of the largest carrier, such as the *Lexington* or *Saratoga* costing approximately forty-four and a half million dollars each, fully equipped, is limited to seventy-two planes, of which thirty-six are of heavy duty type. In considering the cost of air operations in oversea areas, it is inescapable that the cost of carriers and tenders be included. Therefore, it may readily be seen that aircraft have introduced an element of great additional expense rather than of economy in the cost of national defense. In this connection, it is pertinent to call

attention to the confusion of terms that seems to have grown up in the public mind in that national defense is confused with coast and continental territorial defense. The national defense includes the defense of outlying possessions, lines of communication, commercial interests, and lives and property of our nationals wherever located, as well as the defense of the coast and continental territory. The disruption of our commercial intercourse with the rest of the world by cutting the lines of communication across the seas would bring incalculable harm to our economic life.

Having dealt with their limitations, we will now take up what is generally considered a more pleasant task—the capabilities of aircraft in the Fleet. Unquestionably, the potentialities of aircraft in the operations of the Fleet are very great, both before the action is joined and during the battle.

In scouting and observation aircraft have demonstrated their value. Their employment in these functions will increase greatly as the planes are developed to greater endurance and reliability.

In scouting operations, aircraft will prove of great advantage due to their ability to cover quickly areas of ocean within the radius of their operation, as well as to extend the scouting radius of surface craft. Due to the high altitude possible, wider expanses of ocean are brought within range of vision at one time, and the high speed of the planes enables them to scout far ahead of the fleet in much shorter time than can be possible with the fastest surface ships. As said above, the prime requisites for scouting planes are great endurance and efficient radio communication. Although it is possible for an airplane to gain information and bring it back to the commander in chief, it is most advantageous that such information be gotten back by radio, if possible, in order that more time may be given to act upon it.

Another very important function is that of observation. This duty will be performed in closer proximity to the fleet than scouting and the information that a highly trained observer

may give to the commander in chief may prove of inestimable value, in that the types, formation, and tactical movements of the enemy can be given long enough before the fleets are in sight of each other to permit the commander in chief to take such action as may be necessary to bring the enemy to action in situations favorable to himself and unfavorable to the enemy. Dispositions of his forces based on information from aircraft may decide the action. In this duty photography from the air may prove of great value in that the whole scene may be developed and thrown upon a screen for visual study of situations that are well below the horizon. Indeed, this has been accomplished in the Fleet as an exercise.

Aircraft have become indispensable to the Fleet in assisting the control of gunfire by observing and reporting the fall of shot (spotting).

Accuracy of gunfire at long range has already been increased and will be further materially increased by use of airplanes, in view of the possibility of more accurate spotting. The spotter can now obtain a closer and more vertical view of the target and shell splashes from an airplane than is possible from the firing ship, with the consequent far greater accuracy in estimating corrections to be applied for succeeding salvos. The range of effective gunfire also can be increased well beyond the range of vision from any gun or elevated spotting position possible on the ship itself, thus permitting fire to be opened at ranges which greatly increase the effectiveness of plunging hits on the enemy's decks. For spotting duty, it is essential that the spotting plane have efficient radio equipment in order that uninterrupted communication may be had with the firing ship, as the relative positions of the target and shell splashes must be transmitted correctly to the fire-control officer on the ship so that the right corrections may be applied to the guns to bring the hits on the target. Thus, aircraft observation, coupled with radio, has extended the gunner's horizon to the limit of gun range and permits control of gunfire beyond smoke screens.

The offensive power of the fleet has been increased and the range extended by the offensive ability of airplanes to deliver bombs and torpedoes. The projectiles from surface ships can reach only to the extreme range of their guns, but airplanes can drop their bombs or torpedoes far beyond this range. The success of their operations is dependent largely on the defensive measures taken against them. The value of the torpedo plane lies chiefly in the great speed with which the attack is made, but in delivering the attack the planes must descend to within 25 or 30 feet of the water, thereby increasing the risk of their destruction.

In gas warfare, the use of aircraft may constitute a serious menace to ships. Poisonous gas screens may be very effective in forcing a fleet to maneuver to avoid them. The use of smoke bombs and the laying of smoke screens by aircraft are being developed and give promise of effectiveness.

The functions of the lighter-than-air ship in the operations of the Fleet are still in the investigation stage. Although the airship may transport heavier weights to much greater distances than the airplane, its vulnerability to hostile attack even with helium as the lifting gas renders its possible value in war doubtful to say the least. However, it is not safe to make predictions. The experiments now being carried on should finally demonstrate whether or not the airship will be of real value as a unit of the Fleet. Suggestions have been made that airships may be used as airplane carriers and thus furnish their own protection on the scouting line or in action against other aircraft. Also that they may be used in the service of supply for distant operations. A simple arithmetical calculation of weights and distances will answer such suggestions. The largest airship proposed (6,000,000 cubic feet—nearly three times the size of the *Los Angeles*), allowing a safe margin of fuel, would be able to carry a free military load of only ten tons a distance of 4000 miles. As she must carry fuel and stores for the return trip, her radius will be 2000 miles or less. Therefore, in the service of supply, airships will prove exceedingly

costly and quite inefficient. Let us suppose that the ten tons is taken up in airplanes and that the airship is an airplane carrier. I will leave it to you to guess what would happen to the airship when such a weight is suddenly released by sending out the planes. According to my reasoning, there will be only two things that can stop her this side of the moon—rarefied atmosphere or valving of gas. If the latter means is used, what will happen to the airship when her planes come back to her? Unless there is ballast to get rid of, she must come down as she can not carry the weight on reduced gas, and every ton of ballast means that much less military load.

I venture to suggest to you this thought on procurement of material: Under stress of emergency, it takes two years to build a cruiser, eighteen months to two years to build a submarine, two years or more to build a carrier, whereas, with present facilities in the United States, in six months airplanes of approved and developed types can be poured out in quantity production. Incidentally, England, France, Germany, Italy and the United States built during the war 191,000 planes, of which the United States built 19,000.

If some Supreme Being in absolute control of the world could assure us that no war will come upon us in fifty or a hundred years, we could afford to play with our National Defense for awhile. But, failing such assurance, we must accept conditions as they are, and be prepared lest war come upon us in one year or two years or three years, however fervently we may pray "God forbid," and find us without the weapons we know but still dreaming of some super weapon beyond human reach.

For that I submit to you that the following policy is fundamentally sound:

To create, maintain, and operate a Navy second to none; and in conformity with the ratios for capital ships established by the treaty for limitation of naval armament.

To make war efficiency the object of all training, and to maintain that efficiency during the entire period of peace.

To develop and to organize the Navy for operations in any part of either ocean.

To make strength of the Navy for battle of primary importance.

To make strength of the Navy for exercising ocean-wide economic pressure next in importance.

To encourage and endeavor to lead in the development of the art and material of naval warfare.

To cultivate friendly and sympathetic relations with the whole world by foreign cruises.

To cooperate fully and loyally with all departments of the Government.

To maintain that policy, the following is necessary:

In *Battleships.*—Maintain the treaty strength; keep modernized under treaty; apply, under treaty, every device or change that will increase effectiveness of weapons; keep in high state of organization and training.

In *Cruisers, destroyer leaders, and destroyers.*—Create and maintain a tonnage strength based on a 5–5–3 ratio.

In *Fleet submarines.*—Create and maintain a tonnage strength based on a 5–5–3 ratio.

In *Aircraft Carriers.*—Build and maintain at the strength allowed by treaty.

In *Aircraft.*—Create and maintain in numbers, in performance, and in personnel as required to insure a 5–5–3 ratio in naval air strength.

In *Tenders and auxiliaries.*—Provide and maintain as required to support the combatant forces.

Adopt a progressive and adequate airplane building and development program to insure to the fleet at all times a complete outfit of up-to-date planes, with 50 per cent replacements in reserve.

That the completion of the aircraft carriers *Lexington* and *Saratoga* be expedited.

In conclusion, I beg you not to be deceived by dreamers of fantastic and impossible dreams of giant airplanes carrying

tons of explosives and poisonous gases over thousands of miles and destroying whole fleets and cities in a moment, who unfortunately seem to have caught the public imagination and are misleading the people through the press and movies of the country. With their appealing slogans of economy to the effect that a thousand of such giant airplanes can be built at the cost of one battleship, they are seriously endangering our national security.

SCIENCE AND ENGINEERING*

By Doctor M. I. Pupin.

President, American Association for the Advancement of Science.

Mr. President, Mr. Secretary, and friends: I feel that my knees are also shaking like those of Admiral Hughes, although this is not my maiden speech. But it is unnecessary to tell you that a generation ago no one would have ventured to discuss in an assembly like this a double-headed subject—Science and Engineering. In those days a scientist's opinion of engineering did not go for very much, and the engineer's opinion of science went even for less. But the mental attitude is now different, and why it is different I am going to tell you in a few simple words. There was an intellectual movement started right here in the city of Washington 62 years ago, the same year in which President Lincoln delivered his immortal Gettysburg speech. It is this movement which eliminated gradually the difference between science and engineering. There was a time when the people of this country were in a vortex of material activity; they had to reclaim a vast territory between the Atlantic and the Pacific. Thousands and thousands of miles of roads and railroads and populous centers along the tracks were built. Those were the days of the so-called practical man. That was the age of Fulton, of Morse and Goodyear; of McCormick, of Hunt and Howe. They were the idols of the people. The country was too busy to pay much attention to higher sciences. The pulse of intense material activity did not permit any leisure for higher endeavors. This pulse

* Address at Annual Banquet of the American Society of Naval Engineers at Washington, D. C., March 14, 1925.

Europe felt and called it American materialism. This hasty interpretation of our intense material activity was apparently supported by the chaos of the civil war, and many a European philosopher prophesied at that time that American democracy was destined to sink and to disappear in the shapeless mass of its own materialism. But these philosophers were too far away to see clearly that in the smouldering ruins of the civil war there was a spiritual giant, an American idealist, a dynamic idealist, who defied the burning ravages of the civil war—that was great Lincoln. His idealism was the same as that of Washington and of his time. It was the idealism of Lincoln and of the great men of his time which marks the beginning of a new era in American history; the era which finally succeeded in wiping out the imaginary difference between science and engineering.

It was not a mere accident that in the same year in which Lincoln delivered his immortal Gettysburg speech, the National Academy of Sciences was organized, and by its Congressional charter became a part of the Federal government. At that time Joseph Henry, whose statue you may see in front of the Smithsonian Institution, was, and had been for twenty years, the Secretary of the Smithsonian Institution. He was not only a great scientist, he was a great idealist, and a personal friend of Lincoln. Idealism was a force which attracted these two great characters to each other. Hence the organization of the National Academy of Sciences, whose mission was the cultivation of higher endeavors in the intellectual activity of the country. The first act was a movement, a historical movement, in the direction of higher endeavors in science. At the head of that movement were Joseph Henry, John Draper, Frederick Barnard, Andrew White, and other idealists in science. Among them should also be mentioned Daniel Coit Gilman, President of Johns Hopkins University, which was founded in 1876. This great movement succeeded beyond the rosiest expectations even of its most enthusiastic supporters. The

manner in which it succeeded is worth relating here. Johns Hopkins University started with a faculty of seven men. I call it the famous heptagon; it was a constellation consisting of seven stars of the first order of magnitude. President Gilman is credited with saying: "Not bricks but brains constitute a university," and he was right. That faculty, that constellation of seven stars of the first order of magnitude, is in a great measure responsible for the success of that historical movement. It was the first university faculty in the country, smaller in number but greater in achievement than any other university faculty. They gave the guidance and supplied the moving power to that great scientific movement. They sowed the seed which fell upon fertile soil, and the harvest we are reaping to-day. We are seeing its blessings on every side.

In the first place, the American colleges of fifty years ago, with hardly any scientific equipment, were transformed into American universities equipped with splendid laboratories for scientific research, finer than anything they have in Europe, and the men conducting the work in these research laboratories are men of the highest type devoted to the cultivation of higher endeavors in science. This is indeed a revolutionary change. But another change occurred even more remarkable, and I can best describe it by calling it a miracle. The flame of scientific idealism, first kindled at Johns Hopkins University, went from the American universities to the American industries, and the American universities and the American industries formed one harmonious unity, supplementing each other's activity. The industries discovered that the best investment they could make was the investment in scientific research and scientific engineers. The type of men employed to-day by the universities in their most advanced work and the type of men employed by the industries are the same. They are simply highly trained men, trained in science and engineering. The result is that to-day American science and American engineering are welded, and they form one organic unit of living force. They helped

us to advance to the front rank of scientific achievement, and before many years have passed we will be the leaders of the world in science and engineering.

Now what meaning has this in the evolution of the United States Navy? Whenever I hear this name, I always think of Farragut and Ericson. The spirit of Farragut is still the spirit of the men of the United States Navy. That spirit has not changed. It is the same as that of Perry, of Farragut, and of Dewey, and it will never change as long as we take good care of our inheritance of the Anglo-Saxon virtues. But science and engineering in the United States Navy have changed enormously. I often think of the *Monitor* and then of the battle cruisers of 180,000 horsepower. Just imagine, 180,000 horsepower! One of those ships costs as much as a whole big American university, and its scientific equipment is far ahead of the scientific equipment of many universities and industrial laboratories put together. When I think of the planning, of the knowledge, of the skill that must be exercised in order to house all that in one floating structure, I wonder how you men can do it. I consider it one of the greatest, most difficult problems in architectural engineering. It is a miracle.

But here arises a very momentous question, the question, namely, what is the scientific equipment of the men who are entrusted with the management of that wonderful scientific and engineering museum or laboratory? It is a momentous question. I cannot answer it. I am not competent to answer it, because I do not know to what extent that spirit for higher science has penetrated into our Navy. Has it penetrated to the same extent as in the American industries? I do not know, you know it better. Some years ago I went to see Secretary Josephus Daniels to present to him my arguments for the necessity of speeding up the building of the Naval Research Laboratory, and I used among other arguments this argument: "There is more money invested to-day in the United States Navy than in any single American industry, the Standard Oil

Industry and the American Telephone and Telegraph Company not excepted. Now I know that one of these industries is spending nine million dollars annually upon scientific research and development and upon the training and education of its technical staff. Don't you think, Mr. Secretary, that it would be well for the United States Navy to imitate to some extent that example which has proved to be a very profitable one in the industries?" Well, several years after that, I think it was two years, the Naval Research Laboratory was operating at Bellevue, and the number of naval graduates who are sent to the universities for graduate instruction was slightly increased. I think that it was a very fine thing to do. It was a step in the right direction, and with your kind permission I suggest that this step be multiplied tenfold. A friend of mine, an officer in the Navy, told me once that our graduate instruction of the Naval graduates in the universities is doing much to improve the instruction at the Naval Academy. It is a good thing, he said. Well, I said, it is a good thing, but there is another good thing; the presence of your Annapolis graduates improves our instruction at the universities. There is a mutual interchange of favors, and I could not urge more than I have always done that you should send your men as much as you possibly can to get their graduate instruction at the universities. The universities are delighted to see them, they are happy to serve them, because by serving them we serve the United States Navy and we serve ourselves. The presence of these well disciplined men is of most beneficial influence to our university students.

We have agreed to limitation of naval armaments, but we have not agreed to the limitation of naval brains. There is no agreement of that kind. We can go on with the development of naval brains as much as we please. If Lincoln were alive to-day I am sure that he would paraphrase President Gilman's epigram somewhat as follows: "Brains, not bulk, are the best physical foundation for the United States Navy."

THE AERONAUTICAL ENGINE LABORATORY, NAVAL AIRCRAFT FACTORY, PHILADELPHIA, PENNA.

By Lieut.-Comdr. Charles G. McCord, U. S. N., Member.
Superintendent of the Laboratory.

OBJECT

The object of this article is to set forth in a more or less elementary form a description of the Aeronautical Engine Laboratory maintained by the Bureau of Aeronautics at the Naval Aircraft Factory, Navy Yard, Philadelphia.

For the sake of convenience the subject may be divided into two parts, the first a general discussion and description, and the second a short exposition covering somewhat more in detail the apparatus and methods employed in making laboratory tests of aviation power plant material.

PART I.—AIMS

It goes without saying that military aircraft, except balloons, are dependent upon power plant performance. The development of power plants having the necessary characteristics of relative weight, power and reliability to permit their use in the various types of aircraft, must therefore be considered a main factor in design of aircraft and before an engine of new type can be installed in an airship its characteristics must be well determined. Testing of engines in flight is desirable, but ground tests in the laboratory furnish the most reliable and accurate proofs of what may be expected and it is only in the laboratory that careful measurements may be taken of the various functions of engine performance. In the laboratory,

also, the conditions of flight may to a large extent be simulated without the risk sometimes attendant upon experimental work in the air.

In the United States a number of civilian concerns are engaged in design and manufacture of aeronautical engines and accessories and for the most part these companies are equipped with laboratories where their devices are tested. These laboratories are far from being standardized and no two are equipped alike.

In order that the Navy Department may compare the various engines and accessories, check the manufacturer's test results, determine what should be expected from engines of various types, and be in a position to issue specifications for new design and formulate future policy, it is necessary that a power plant laboratory be maintained where tests may be conducted by government personnel.

To obtain the proper conditions for testing power plant equipment and to compile in correct and authoritative form the results of the tests, is therefore the aim of the Laboratory.

Several branches of the government, notably the War, Navy and Post Office Departments, are vitally interested in the development of aviation and every effort is made to coordinate the work. To prevent duplication and to harmonize the various activities, assignment of test projects to the laboratory is made by the Bureau of Aeronautics where close touch is maintained with the work proceeding at McCook and Langley Fields, the Bureau of Standards, and other places, where similar development work is being carried on.

Some idea of the scope of the laboratory work can be gained from an inspection of the following list of tests and studies that have been completed or are being made at this time:

Tests and studies of accessories such as,
pumps for fuel, oil and water,
intake and exhaust valves,
pistons, rings and bushings,

ignition systems,
mufflers,
special bearings and packing material,
instruments,
carburetion problems.

Miscellaneous tests and studies such as,

fuel investigations,
laboratory and flight tests of water recovery apparatus for the U. S. S. *Shenandoah*.

And most important of all, the measurement of power plant performance of which the following are important factors.

power,
specific fuel consumption,
heat balance,
carburetion,
adjustments for best power or best economy,
altitude performance,
effect of catapulting,
endurance tests of long duration.

Methods and apparatus necessarily will be altered to fit the circumstances as they arise in making tests, which are of great variety.

Many of these tests are being standardized in the light of experience gained by repetition, but as a rule equipment to suit the needs of the various tests must be constructed or adapted from material on hand. The instruments used are of considerable variety and it has been found expedient to maintain an instrument shop, under the supervision of an expert in that line of work, where instruments already conditioned and calibrated may be drawn by the engineers as necessity arises. All instruments are numbered, and calibration sheets are kept up to date. Manufacture of special instruments is carried on in this department.

Certain determinations can be made only under the conditions of actual flight. Under this head might be listed: the test of the water recovery apparatus now on the U. S. S. *Shenandoah,* where all flight conditions could not be duplicated on the ground; and the test to determine the cause of stoppage of certain engines when the planes in which they are installed were launched from catapults.

Work of this character falls within the scope of the activities of the laboratory.

HISTORY.

For experimental and testing purposes along the lines of power plant development, a testing laboratory was established in the Washington Navy Yard in 1915. At that time only the simplest equipment was necessary and provided. A building on the waterfront, previously used as a storehouse, was assigned for housing the equipment, which as aircraft activities and material development progressed, became crowded and inadequate, and due to the limited space and necessarily temporary nature of the quarters provided, the facilities fell behind the minimum requirements for the work to be done. Further expansion at Washington Navy Yard was impossible and impracticable.

To meet the urgent and increasing demands of Naval Aviation activities, the housing of the laboratory in more suitable quarters became necessary and following the establishment of the Bureau of Aeronautics a new site was selected for the laboratory.

The Naval Aircraft Factory at Philadelphia came into being during the war and this was selected as the logical site for the new laboratory for the following reasons:

(*a*) The Naval Aircraft Factory is the principal source of supply for all Naval Aviation units.

(*b*) Space is available to house the laboratory.

(*c*) Test work is carried on in flight; and test planes, both land and sea, are available. A landing field, ramps, hangars, catapults and operating personnel are available for test flying.

(*d*) Philadelphia is relatively close to the plants of manufacturers of instruments and engines and much of the material to be tested.

(*e*) A supply system accustomed to handling aeronautical material is already established at the Aircraft Factory.

(*f*) To coordinate aircraft and aircraft engine design, manufacture and testing.

Purchase of equipment was begun and the necessary building changes made. In April, 1924, the Washington laboratory was closed and test work transferred to the Aircraft Factory and work begun earlier in the year was carried on while construction was still in progress. Most of the personnel was transferred to Philadelphia and the organization became a part of the Naval Aircraft Factory, the Superintendent coming directly under the Manager of the factory.

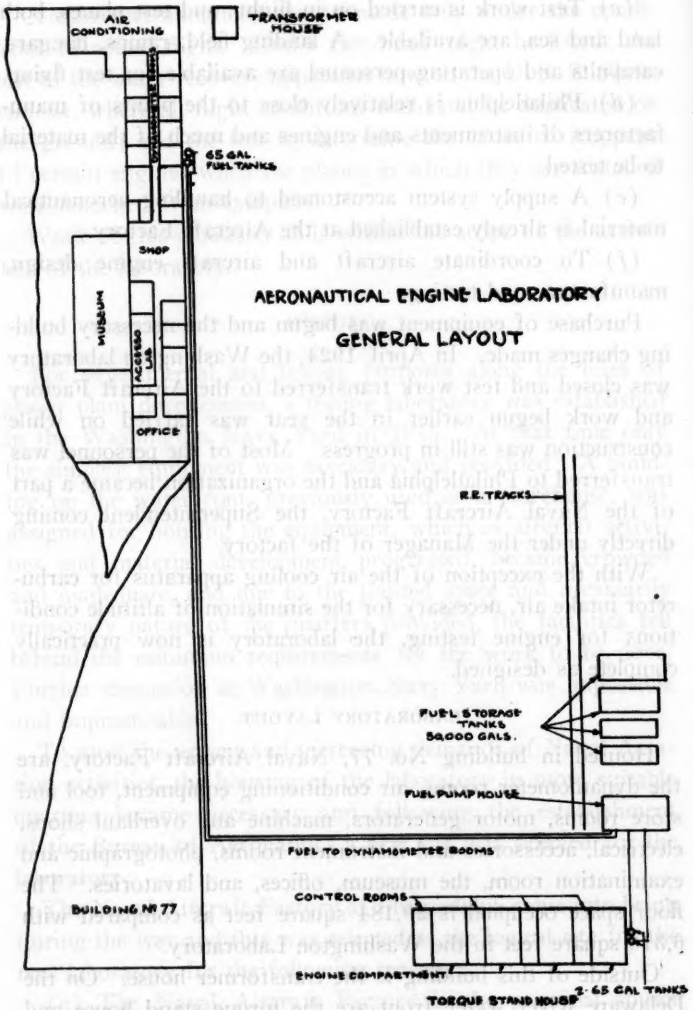
With the exception of the air cooling apparatus for carburetor intake air, necessary for the simulation of altitude conditions for engine testing, the laboratory is now practically complete as designed.

LABORATORY LAYOUT.

Housed in building No. 77, Naval Aircraft Factory, are the dynamometer rooms, air conditioning equipment, tool and store rooms, motor generators, machine and overhaul shops, electrical, accessories and instrument rooms, photographic and examination room, the museum, offices, and lavatories. The floor space occupied is 29,184 square feet as compared with 6,316 square feet in the Washington Laboratory.

Outside of this building is the transformer house. On the Delaware River water front are the torque stand house and fuel storage and handling systems.

Arrangements have been made so that engines under test are set up in separate rooms, thus avoiding noise and confusion.


AIR CONDITIONING
TRANSFORMER HOUSE
65 GAL. FUEL TANKS
SHOP
MUSEUM
ACCESSORIES LAB.
OFFICE
AERONAUTICAL ENGINE LABORATORY
GENERAL LAYOUT
R.R. TRACKS
FUEL STORAGE TANKS 50,000 GALS.
FUEL PUMP HOUSE
FUEL TO DYNAMOMETER ROOMS
CONTROL ROOMS
BUILDING Nº 77
ENGINE COMPARTMENT
2-65 GAL. TANKS
TORQUE STAND HOUSE

The number of individual projects that can be handled at the same time is considerable, ten dynamometer rooms and four engine rooms being fitted with engine stands, any or all of which may be used independently.

DYNAMOMETER ROOMS.

Ten rooms are provided for dynamometer tests of engines. Three of these are for air cooled engines, one for carburetor testing and the remaining six for water cooled engines. Seven of the rooms are equipped and in use.

The rooms are all fitted with slotted bed plates to accommodate the dynamometers and engines and all are connected to the carburetor air cooling system and to altitude and sea level exhaust systems.

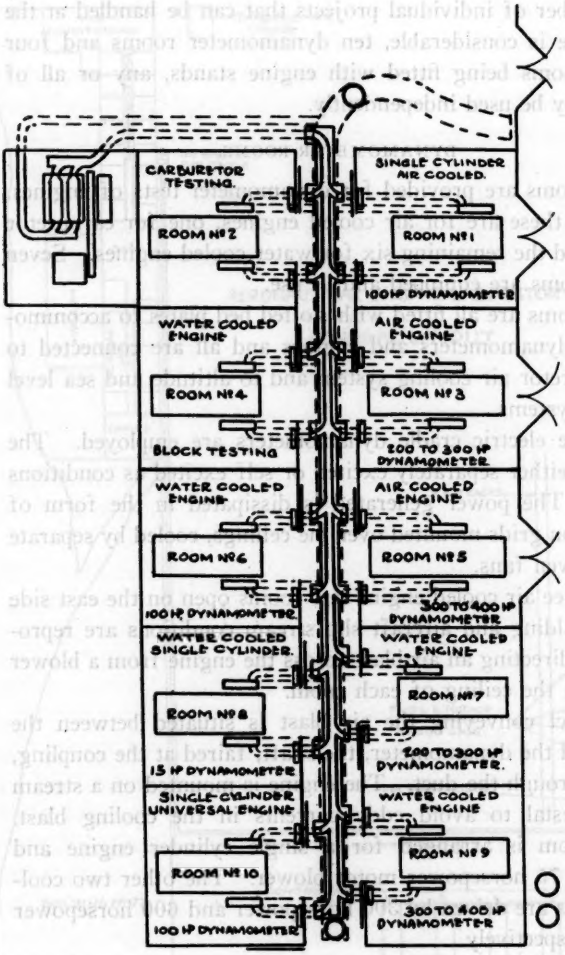
Sprague electric cradle dynamometers are employed. The fields are either separately excited or self excited as conditions require. The power generated is dissipated in the form of heat in iron grids mounted over the ceilings, cooled by separate motor driven fans.

The three air cooled engine test rooms open on the east side of the building and aircraft slip stream conditions are reproduced by directing an air blast across the engine from a blower located on the ceiling of each room.

The duct conveying the air blast is situated between the engine and the dynamometer, the shaft, faired at the coupling, passing through the duct. The engine is mounted on a stream lined pedestal to avoid eddy currents in the cooling blast. No. 1 room is arranged for a single cylinder engine and employs a 75 horsepower motor blower. The other two cooling blowers are driven by 300 horsepower and 600 horsepower motors, respectively.

POWER REQUIREMENTS.

Power for the blowers and for dynamometer fields, as well as for the Nash and Robinson blowers for handling the exhaust and for other laboratory uses, is taken from the Navy Yard



DYNAMOMETER ROOMS
SHOWING ALTITUDE & SEA LEVEL
EXHAUST SYSTEMS

Power House. A transformer house outside and a motor generator room inside building No. 77 provides for five systems of power required for the part of the laboratory in that building. This includes alternating current at 2300 volts for the motor generators and large blowers, alternating current at 220 for refrigerating and exhaust motors and general laboratory use. This is used for three phase and single phase motors. Constant potential direct current at 220 volts for dynamometer field excitation and 220 volt direct current and 110 volt direct current for general use, are produced by two motor generators of 150 and 75 kw. capacity, respectively.

In the torque stand house and pump house alternating current is employed for lighting, starting engines, carburetor, air heating, pumping fuel to distributing tanks and for small power tools. Transformers on the outside of the torque stand house furnish this power.

WATER REQUIREMENTS.

Water is provided in the dynamometer rooms for engine and exhaust cooling and for water brakes. The Nash exhauster requires water for operation as does the refrigerating machinery.

Hot and cold water are supplied to the wash rooms and showers and cold water to sinks in the instrument and accessories laboratories and the forge shop.

The water for torque stand engine cooling is led in from mains on the water front and the main supply for the remainder of the laboratory from mains under Porter Avenue.

TORQUE STAND HOUSE.

For tests of engines under propeller load conditions four rooms are fitted up in a reinforced concrete structure on the water front. Reaction torque stands are mounted in these rooms and each engine room has an individual control room adjacent to it, in which the engine controls, gage boards and

measuring instruments are located. This tends toward safety for operating personnel and removes the instruments, to a considerable extent, from the dirt, oil and vibration incident to engine operation.

A trench extending from end to end of the building below the floor level serves as a conduit for electrical, water, oil, fuel, air and steam leads.

Large doors open at the ends of the engine rooms providing a free flow of air when the engines are running.

TORQUE STANDS.

Four torque stands are provided for testing engines under propeller load conditions. The engine to be tested is mounted on a metal stand so arranged that the crank shaft axis and axis of the cradle coincide. The cradle turns on ball bearings.

A torque arm of convenient length is secured to the cradle and torque measurement in foot pounds is read by the mercury dash-pot and scale method as on the electric cradle dynamometers, described later.

Ordinarily flat moulinet propellers or those of slight pitch are used to absorb the power where water cooled engines are under test. For air cooled engines where a slip stream is essential, service types of propeller are employed, the characteristics being such as to give the desired speed at full power.

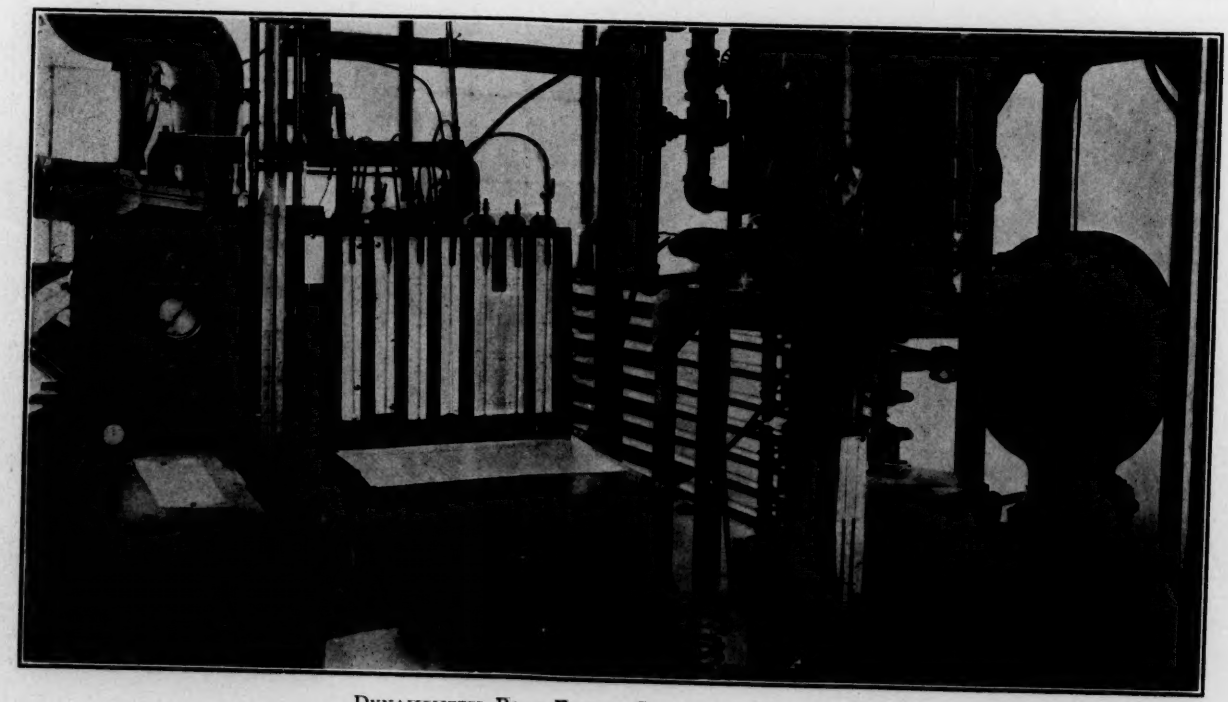
When using moulinets or propellers, it is necessary to eliminate the negative torque reaction due to the whirling slip stream impinging on the engine so air rectifying grids are inserted between the engine and the propeller. These grids straighten the path of the air stream and satisfactory results are obtained.

Controls and pipe leads are so arranged as to interfere as little as possible with correct torque reading. The motion of the stand cradle is very slight.

Before each day's run the scale is calibrated by hanging weights on the torque arm.

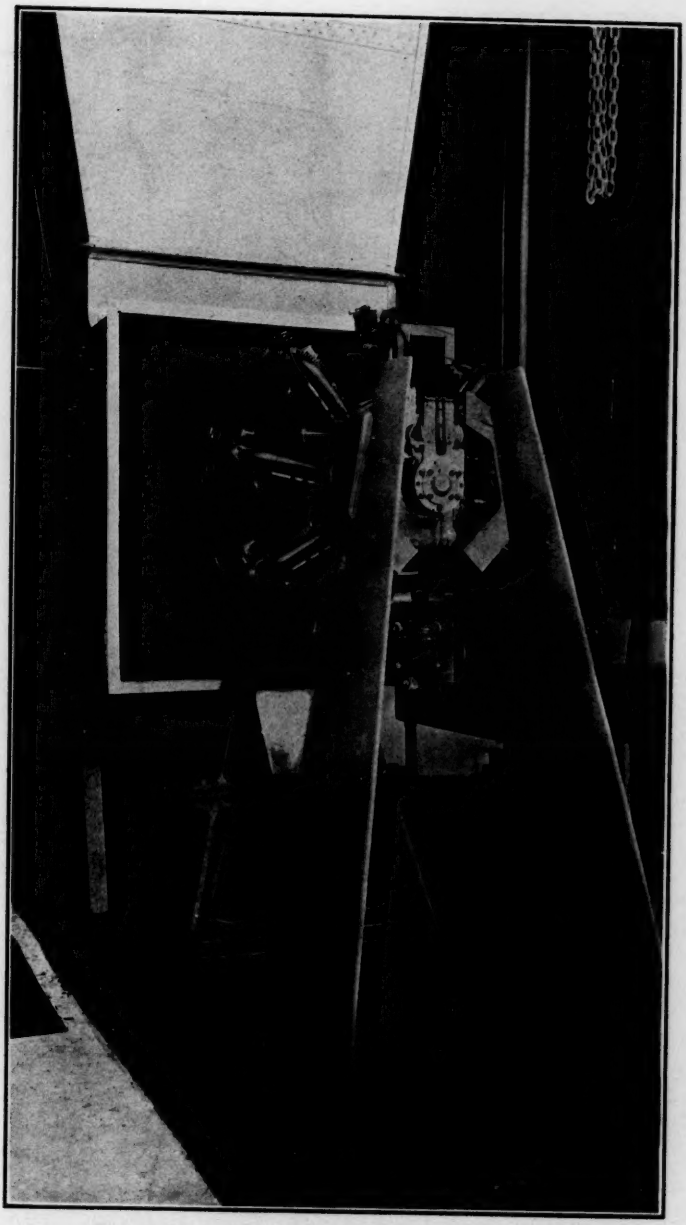
NAVAL AIRCRAFT FACTORY.

OVERHAUL, MACHINE AND WELDING SHOPS.

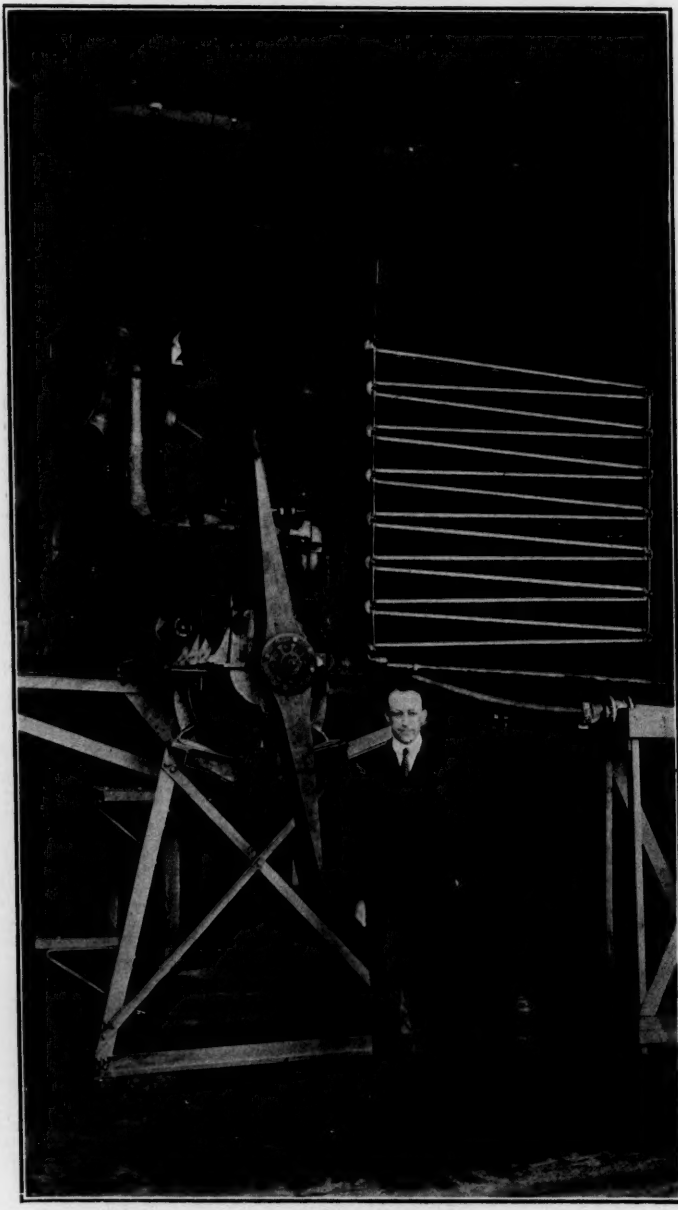


DYNAMOMETER ROOM ENGINE CONTROL AND GAGE BOARD.

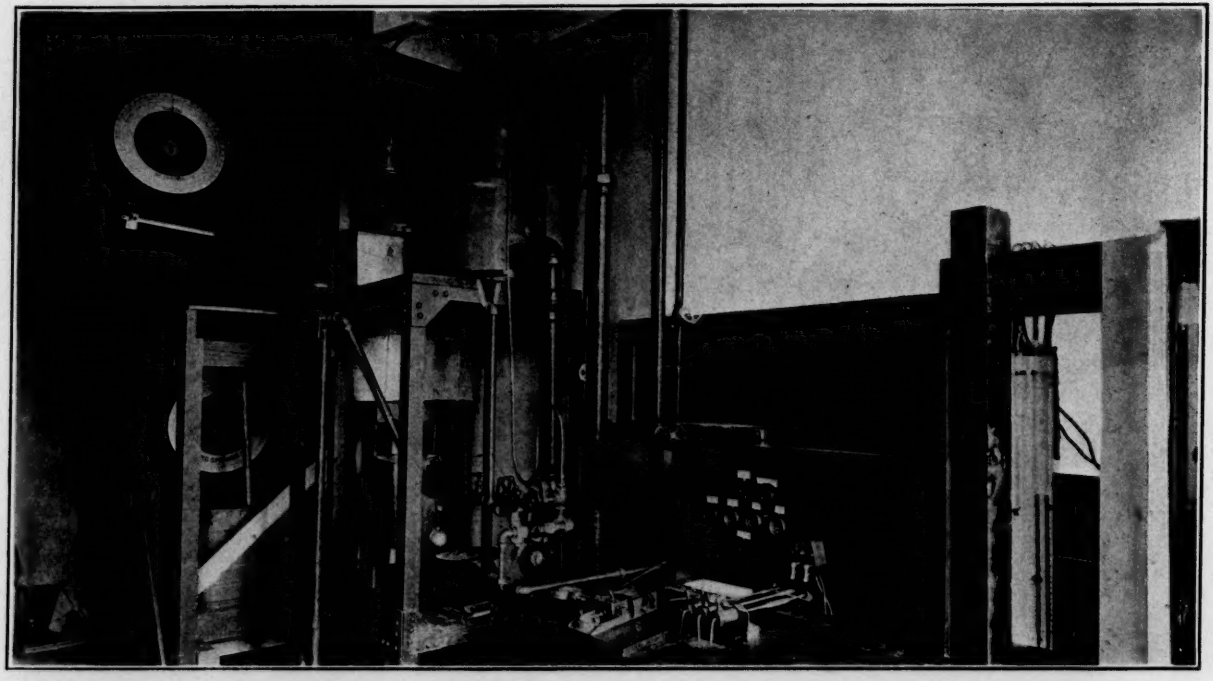
INSTRUMENT LABORATORY.



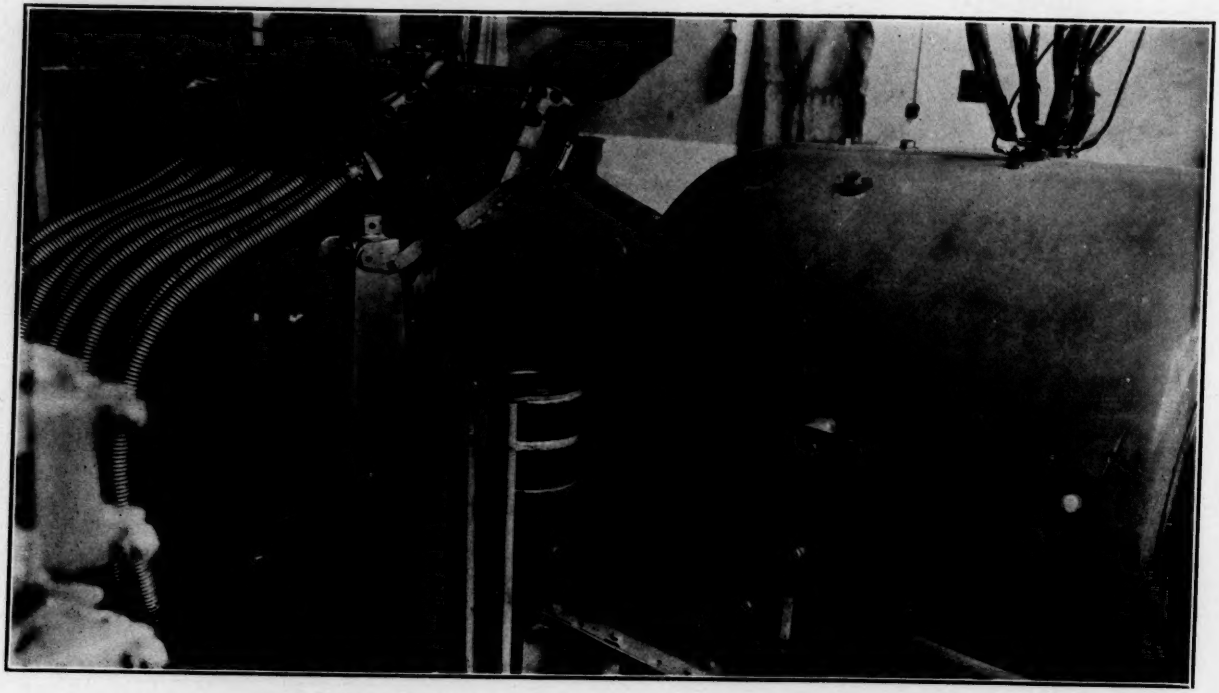
DYNAMOMETER RIG FOR AIR COOLED ENGINE TESTS.



REACTION TORQUE STAND WITH PACKARD ENGINE MOUNTED, USING FLAT MOULINET TO ABSORB POWER.—(RIG USED IN LABORATORY TEST OF WATER RECOVERY APPARATUS FOR U. S. S. "SHENANDOAH.")



CONTROL ROOM IN TORQUE STAND HOUSE SHOWING ENGINE CONTROLS AND MEASURING INSTRUMENTS.



A. E. L. Type Dynamometer Scale Apparatus for Torque Measurement.

FUEL SUPPLY SYSTEM.

Four large underground tanks of 50,000 gallons total capacity are provided for storage of fuel. Two gravity tanks are located adjacent to the torque stand house and two more outside the dynamometer rooms. These tanks are each of 65 gallons capacity, mounted on structural iron stands to provide gravity flow to the individual engine and control rooms.

Supply of fuel to the gravity tanks is effected by five pumps located in a pump house at the storage tanks and two kinds of fuel can be made available for comparative tests at either the torque stand house or the dynamometer rooms by the simple piping system connecting with the gravity tanks.

The system is very flexible. Provisions are made for automatic control, and a flame-valve drainage system saves fire risk. All pumps are fitted with meters.

SHOPS.

The machine and overhaul shop is centrally located and adjoins the welding shop, the photographic and measuring room and the stock and tool rooms.

The overhaul benches are ranged on one side of the room and the engines for overhaul may be pushed in between the benches on stands mounted on castors. The benches themselves are of special design, a horizontal rod above the bench carrying elevator buckets for keeping small parts segregated. The buckets containing the parts may be dipped into a liquid cleaner for removing grease.

Engines and larger engine parts are cleaned by dipping in a steam heated vat containing soap powder solution. Air and electrical connections are provided at the benches for portable tools.

On the other side of the same compartment is the machine shop with lathe, shaper, milling machine, drill press and power saw equipment sufficient to cover the ordinary needs of the

laboratory. All regular manufacturing work is done in other parts of the Aircraft Factory and the laboratory shop is maintained only for handling small jobs incident to test work. The welding shop is an important unit as engine rigging on the test stands necessarily requires a large amount of pipe work and small welding jobs.

The tool room and adjacent stock room form a source of supply for the entire laboratory.

The photographic and examination room is the location for a large surface plate and for such apparatus, exclusive of camera, as is required for accurate measurement of engine parts on overhaul and for photographing the parts for aiding description in report compilation.

ACCESSORIES, INSTRUMENT AND ELECTRICAL LABORATORIES.

The accessories laboratory, used for most tests where it is not required that engines be run, is equipped with heavy slotted bed plates for mounting equipment, a drainage trench, water and electrical leads and a variety of small dynamometers, motors and stands for test rigs. Jet flow testing gear, vibration tester, impact machine for magnetos, ignition distribution and spark gap testing devices are located in this compartment.

In the electrical laboratory the various meters and tools for ignition work are kept.

The function of the instrument laboratory is to manufacture, calibrate and keep in condition the instruments used in the test work. Small precision tools are installed, including a fairly complete watchmaker's outfit.

Standard weights, thermometers and hydrometers for calibration purposes in the laboratory have been checked by the Bureau of Standards.

Records of calibration are kept up to date so that they are available for the engineers collecting test data from the instruments on test layouts.

Equipment of this room includes a specially designed tachometer calibrating instrument and thermometer calibrating apparatus of various kinds.

HANDLING FACILITIES.

A travelling crane traverses the shops and minor laboratory rooms and each dynamometer room and torque stand engine room is fitted with its own chain fall travelling on a centrally situated rail. A somewhat massive stationary crane structure spans the corridor between the inner and outer dynamometer rooms.

OIL COOLERS.

Much time and money have been expended on securing a reliable and efficient type of oil cooler for laboratory use. The most successful cooler tried has been a few coils of ice machine condenser piping such as that in service on carbon dioxide ice machines. The straight pipes and excellent jacketing, which can be used for heating the oil with steam or cooling with water as conditions require, make this apparatus ideal for laboratory use.

MUSEUM.

In order to make use of the successes and of the failures of the past in the development of aeronautical engines a museum has been started in conjunction with the laboratory in which are located current, obsolescent and obsolete engines, American and foreign, and examples of parts and accessories from the earliest available to the present time.

It is hoped that in time the value of such a museum may receive sufficient notice to permit its being properly housed, the engines well mounted, and, in some cases, sectioned to show the internal parts.

Between forty and fifty engines have been obtained to date for display in the museum.

OFFICE.

The office is designed to furnish desk space for the supervisory, technical, clerical and drafting force. An enclosed private office accommodates the superintendent, assistant and senior engineer.

A considerable amount of drafting is required in connection with test rigging and design of equipment. Occasionally design of engine parts is required and the preparation of reports calls for line sketching and a large amount of curve plotting. For this purpose a drafting force is maintained and equipment provided.

A technical library is maintained with such books as are obtainable on power plant subjects and files of technical magazines, test reports from the Bureau of Standards and from other government and private sources.

Calculating machines and the usual aids employed in engineering work are furnished for use in compiling reports.

ORGANIZATION.

The organization of personnel in a testing laboratory should be such that no individual should be indispensable. To this end the mechanics and engineers' duties should be generalized and so far as possible no specialization system should be adopted. This can not be made to apply to special trades such as joiner, welder, instrument maker or electrician, but for the good of the laboratory it seems desirable to avoid having a machine tool group or an engine overhaul group specialized in those particular lines of work to the exclusion of all else. The wider the range of knowledge based on the experience of the men, the more useful the organization will be. Variety adds to the interest in the work, although it has been the experience of the writer that keen interest is manifested by the mechanics and engineers alike in all forms of test work in the laboratory and the desire to secure accurate, reliable and conclusive results characterizes the laboratory personnel.

As above stated, the organization should be flexible and for assignment to duties divides itself naturally into the following classifications:

(A). ADMINISTRATIVE GROUP.

Under this head come the Superintendent and Assistant. These should be naval officers. The engineer of tests, a civilian engineer, is the technical assistant to the superintendent and is charged with the duties of assignment of test work and in general of planning and estimating.

(B). ENGINEERS.

The present organization calls for two associate engineers, three assistant engineers and eight junior engineers.

The associate and assistant engineers plan and oversee test work, compile data and write the test reports which are edited by the administrative group and approved before issue. The junior engineers follow the work in the shop and on the test stands, conduct minor tests, collect data, calibrate equipment and relieve the engineers of the more important tests of detail work in order that more time may be devoted by the latter to planning and report work. A physicist is at present included in this group.

(C). DRAFTING GROUP.

The four draftsmen are kept busy with curves, calculations in connection with test data, design of equipment and parts and to some extent with calibration and test work. This is very desirable in order to have the designers familiar with the usual methods of test and with the material.

(D). STENOGRAPHIC, CLERICAL AND FILING GROUP.

Correspondence, report typing, maintenance of technical and correspondence files and the technical library form the duties of this group. Time keeping, stock-chasing and upkeep of schedule and job order systems may also be included as part of their work.

(E). MECHANICAL SUPERVISORS.

The care and maintenance of equipment and buildings, supervision of mechanics, set up of test material and repairs under the direction of the engineers are the duties of the Supervisors. At present one quarterman and a leadingman are employed.

(F). MECHANICS, HELPERS AND JANITOR.

For general mechanical work, upkeep, tool and stock room maintenance and conducting tests men of trades below listed are employed:

machinists, 15; aircraft mechanics, 6; electricians, 2; sheet metal workers, 2; instrument maker, 1; joiner, 1; helpers, 5; janitor, 1.

Photographic, mimeographic and blueprint work are at present being done by the Aircraft Factory organization, outside of the laboratory.

The plan is to assign to a major test project a test engineer, a junior engineer, as many mechanics as required, and to have this group follow the test through from receipt of the material to publication of the report. Thus in case of an engine test the same group would have charge of estimate, preliminary overhaul and measurement, preparation of equipment, photographing, dynamometer characteristic tests, including friction horsepower determination and altitude runs, propeller load tests, repairs, final overhaul and measurements, compilation of data and report writing.

REPORTS.

It is through reports submitted to the Bureau of Aeronautics and issued by the Bureau that the laboratory can be of value to the service and only by accurate and dependable results set down in such a way as to be intelligible can the laboratory justify its existence.

Reports are issued in a standard form and size. The text matter, formerly blueprinted, is now being mimeographed and a mimeoscope has been added to the office equipment by means of which line sketches and similar matter may be mimeographed for the sake of uniformity.

Engine data sheets being too large for mimeographing are, as a rule, blueprinted and where necessary mounted photographs and photostats are included in the reports.

The highest aim of the laboratory is to turn out for issue reports of real value to the service and of such accuracy that they may be considered authority on the subject of aeronautical power plants.

SAFETY DEVICES.

To prevent the wrecking of an engine on the dynamometer stand, in case field power should fail from any cause, a no-voltage cutout was devised to open the ignition line in case of a drop in the dynamometer field voltage. This consists of a solenoid operated switch, which cuts out automatically the engine ignition circuit.

Reinforcement of walls separating the engine rooms from the control rooms in the torque stand house and expanded metal doors to prevent flying of broken parts and entry of persons from outside the building when engines are running or about to be started, are among the safety precautions employed.

As a rule aviation engines running in a confined space are noisy enough to make it disagreeable for an outsider to remain in the compartment and no bars are required to keep those not interested in the work away from them.

Guards are placed over couplings and fly wheels to prevent clothing becoming entangled.

Men working in the dynamometer rooms have complained from time to time of severe backache due to constant vibration. Heavy rubber matting placed on the floor where the men stand seems to cure this. The deafness resulting from engine noises

is temporary and no serious impairment of hearing has been reported. Cotton or rubber protectors in the ears deaden the sound and the effect of the constant jarring noise wears off in the course of a few hours.

The danger to personnel in engine testing comes from fire, explosion of gas, breakage of parts or contact with moving parts such as propellers and couplings.

Every effort is made to cut down the risk of injury by fire and explosion by keeping tight joints in fuel lines, avoiding the use of gasoline or other inflammable material outside of the engine rooms, proper ventilation to force any accumulated fumes out of the engine rooms and by providing fire extinguishing apparatus wherever necessary. Pyrenes and Foamite extinguishers are kept on hand in the engine rooms and frequently tested. Blankets for smothering flames, burning oil or gasoline soaked clothing, are kept hanging in all engine rooms in use.

The matter of ventilation of rooms is considered especially important as either gasoline fumes or exhaust gases in confined spaces may cause serious consequences to personnel.

In this connection it might be of interest to note that although large quantities of tetra-ethyl lead have been used in test work in the laboratory, no bad effects have been noticed by the employees using it, either from handling the fuel or from the exhaust fumes to which they have been occasionally exposed.

In the dynamometer rooms the altitude and sea level exhaust pits are connected through ducts to the blowers, and one or both blowers are running when engines are being tested. The air exhausted is replaced from overhead.

Under sea level conditions the rooms are constantly ventilated, as the exhaust stacks are open and all fumes are swept through them.

When tight exhaust and carburetor intake are employed, as in making altitude tests, care must be used to trap fuel over-

flow, and keep tight fuel line joints. A draft is induced in the room in this case through the door and windows or overhead openings.

Explosions in the exhaust ducts are within the realm of possibility. To prevent danger to personnel should such an explosion occur, there are manholes at either end of the sea level duct and a light door is placed in the sheet metal riser to the exhaust fan, that can be blown open to allow the force of an explosion to expend itself harmlessly. Water flowing in this duct adds to the safety, all cooling and water brake overflow passing through this duct to the sewer.

PART II.

For ordinary engine testing the following data are usually taken and are plotted or tabulated for report:

Readings, time; revolutions by counter; torque in foot-pounds; brake horsepower (observed and corrected); fuel consumption in pounds per hour; specific fuel consumption; carburetor temperature and pressure; oil pressure; water temperature rise and flow; oil temperature rise, flow and consumption; manifold vacuum; room temperature and barometer; altitude control setting; air venturi reading (carburetor supply); air flow in pounds per minute; volumetric, thermal and mechanical efficiencies; air-fuel ratio; jacket water losses expressed in percentage of brake horsepower.

Determination of compression ratio, timing, both valve and ignition, and photographing and physical description are items that usually precede the placing of the engine on the test block and note is made of date, type of fuel, make and characteristics of carburetor, ignition system and spark plugs. Casualties and replacements are carefully recorded.

TESTING AND APPARATUS.

Engines are tested ordinarily at sea level conditions of temperature and pressure. The performance at high altitudes may be roughly calculated from the data thus obtained, but where

it is desired to test the engines under real conditions encountered at altitudes above sea level, the laboratory must be located at the desired altitude, the test must be made in flight or the altitude conditions must be simulated by artifically producing the same temperature and pressure corresponding to the desired altitude.

Volumetric efficiency, and consequently available horsepower, is affected by variations in air density and the effect as altitude increases is to cut down the power. This is shown by indicator cards.

In order to obtain altitude conditions in the laboratory recourse is had to the following means:

(*a*). Pressure at the exhaust outlets is reduced to a minimum of one-third of an atmosphere by tight connections to a pipe leading to a Nash Hytor exhaust air pump.

(*b*). Temperature of the carburetor intake air is reduced to a minimum of 58 degrees F. by a refrigerating plant and adjusted to the desired temperature by electric heaters and by throttling.

The extreme conditions above noted permit the reproduction of altitude conditions approximating 30,000 feet.

At this writing the manufacture of the refrigerating equipment has not been completed.

LABORATORY STANDARD METHODS OF TAKING TEST DATA.

Gasoline consumption measured in pounds per hour and usually tabulated in the form of pounds per brake horsepower per hour (specific fuel consumption), is measured by a flowmeter or by taking the time by stop watch for the consumption of a given weight of fuel.

Of flowmeters two different types are in use in the laboratory, both being sensitive and positive in action. One type consists of a vertical column of fuel enclosed with a glass front, in which a brass disc or pill rides at a height corresponding to the rate of flow. This column is calibrated and scaled to read in pounds per hour. The scale must be altered or the reading corrected when different fuels are used.

The rotary type of flowmeter depends for its action on the pressure of fuel against a rotating vane, the pressure being opposed by a coiled spring. This instrument is small and can be used in aircraft as it does not have to be kept in an upright position as in the case of the vertical type. The internal parts of this instrument have been gold plated but where the plating has been scratched an error has been introduced due to corrosion of parts.

For weighing and timing fuel consumption a small torsion balance is employed in conjunction with a solenoid operated stop watch. A large bottle contains the fuel. The balance on which the bottle rests is connected with a mercury contact device, which actuates a solenoid and plunger which strikes the stem of the stop watch when the balance is reached. A positive revolution counter is included with the device so that the time and revolutions are taken at the same instant.

Several types of tachometers are in use, the best results being obtained with the Veeder vertical scale instrument, in which the height of a liquid column is read on a scale showing revolutions per minute. A rotary pump in the tachometer base, connected by a flexible drive shaft to the engine, raises the column of liquid in a tube and furnishes an accurate means for obtaining the revolutions per minute. This is a laboratory instrument and is not considered suitable for instrument board installation in service aircraft.

Chronometric and other standard types of tachometers are also used on the instrument boards in the various rooms.

MEASUREMENT OF TEMPERATURES.

For the measurement of temperatures of the various parts of engines and particularly of oil, water and air, there are several means available. Mercurial thermometers and distant reading thermometers of the type usually supplied to aircraft have their uses, but for obtaining accurate engine test data it has been found necessary to use thermo-couples or resistance thermometers reading on galvanometers conveniently placed with regard to the engine control boards.

PRESSURES AND AIR SPEEDS.

For ordinary pressures, such as oil and water inlet and outlet pressures, the instruments usually supplied for aircraft instrument-boards are employed. Manifold vacuums and small pressures are obtained by means of manometer tubes. For air speeds, Pitot tubes with inclined manometers or Zahm instruments combining the Venturi and Pitot principles are used.

OIL, WATER AND AIR FLOW.

The use of Venturi meters for measurement of air and water flow in the laboratory required the manufacture of special instruments. For convenience in handling, aluminum castings were employed. These were cast and machined at Washington Navy Yard and made of such sizes that the throat castings for one size could be used for inlet and outlet sections for the next smaller size; thus 8-inch instruments have 4-inch throats, 4-inch have 2-inch throats, 2-inch have 1-inch throats and 1-inch have ½-inch throats.

It was believed that these sizes would cover all ordinary ranges of flow. Practice, however, proves that 3-inch throat Venturi meters for carburetor air flow are required for the medium powered engines now in use. The air fuel ratio must vary considerably under various test conditions and its measurement with relation to other performance functions is of considerable importance. For best combustion the ratio, by weight, of air to fuel is normally about 12:1 to 15:1; thus an engine developing 300 brake horsepower with a specific fuel consumption of .5 pound per brake horsepower per hour will require 1800 to 2250 pounds of air per hour. For measurement of this flow, a Venturi meter of such dimensions as to permit a differential reading on a manometer of sufficient height of water column, is very desirable.

Calibration of the Venturi meters used for measurement of water flow is a relatively simple matter. New Venturi meters have checked closely with computed flow figures. The experi-

ence with aluminum meters has been, however, that corrosion and deposit of a rough coating inside the Venturi tube will destroy the accuracy of the readings. Heat treatment with sodium silicate has been used to advantage in preventing corrosion.

The fire nozzle type of meter is found useful and accurate in measuring water flow at the return pipe outlet to water tanks.

Oil flow is determined by weighing the amount of oil returned through the engine system to a tank mounted on a beam scale.

The consumption of oil is recorded, it being the amount added from time to time as a test progresses. The original and final quantities in the system are weighed.

In the case of air measurement for carburetor tests, a metering box with various sizes of metallic orifices has been provided.

The time and engine revolutions per minute required to burn a given weight of fuel is obtained by placing the fuel in a bottle from which the fuel is piped to the carburetor. The bottle is mounted on a torsion balance in such a manner that when the balance trips, on completion of the draining of the given amount of fuel, an electrical contact is made which by a solenoid arrangement stops a counter and a stop watch simultaneously.

MEASUREMENT OF TORQUE.

Torque measurement on the electric cradle dynamometers, either acting alone or coupled to a water brake, is usually accomplished by means of beam scales or some form of platform scale. It has been found better, as regards facility of reading and sensitivity, to extend the torque arm downward with a ball joint and a steel tubing member to a mercury dash pot directly beneath the end of the torque arm. This pot contains a piston, acting on mercury contained in the pot and by suitable pipe connections, forcing a mercury column up a glass tube on the instrument and control board to a height proportional to the torque. The height then gives readings on a

calibrated scale, directly in pounds of torque. Syphons are employed in some cases to avoid the difficulty experienced in keeping mercury dash-pots tight. The scales read in pounds torque or directly in mean effective pressures.

In the case of torque stands, where the engine power is absorbed by a propeller or moulinet, the same system is employed and the readings are found to be extremely accurate.

LENGTH OF TORQUE ARMS.

On the electric cradle dynamometers or the torque stands much computation may be saved, where brake horsepower is obtained from torque readings, by having the torque arms of such length that the use of a simple constant as a divisor will give the required horsepower.

When an arm sixty-three inches in length is used, the brake horsepower is obtained by dividing the product of the revolutions per minute and the load in pounds by one thousand. With an arm of twenty-one inches, the divisor is three thousand. This is a more convenient length for ordinary use.

$$\text{H.P.} = \frac{2\pi WNl}{33{,}000} \text{ where } l = \text{torque arm in feet.}$$

$$\text{Assuming } \pi = \frac{22}{7} \text{ and } l = \frac{63}{12} \therefore \text{H.P.} = \frac{2 \times 22 \times WN \times 63}{7 \times 33{,}000 \times 12}$$

$$= \frac{WN}{1000}$$

In case the mercury scale is calibrated to read in pounds per square inch mean effective pressure, instead of foot pounds torque, a moveable fulcrum is provided, so that a variable length of lever arm is interposed between the end of the torque arm and the mercury dash-pot, the lever values being calculated for the engine in use.

AIR CONDITIONING.

Under ordinary conditions of running, for engines under test on the electric dynamometer, the air is supplied under atmospheric conditions existing at the time, and the exhaust is

collected in open exhaust ducts and drawn through a large common duct passing under the floor of the corridor separating the rows of dynamometer rooms, from which it is expelled by a 30-horsepower Robinson blower over dynamometer room No. 1.

This gives the sea-level condition which is reduced to standard air condition by calculation.

When it is desired for any reason to submit an engine to test, under conditions simulating those encountered in flight, it becomes necessary to cool the intake air to the carburetor and to reduce the atmospheric pressure of the exhaust to a degree depending on the altitude simulated.

To supply the proper amount of air at a low temperature (minus 58 degrees F.) a refrigerating plant is being provided consisting of:

(1). A dehumidifier wherein the entering air is blown across a cascade of brine cooled by a small ammonia ice machine, leaving the air in a comparatively dry condition.

(2). CO_2 refrigerating machines, either one or both of which can be used in cooling the dehumidified air.

(3). A box for trapping any snow that remains in the air up to this point.

(4). A heavily lagged distributing system with four booster boxes for further cooling the air before it enters the ceilings of the dynamometer rooms.

Temperature of the carburetor intake air is reduced to a minimum of 58 degrees F. by the refrigerating plant and adjusted to the desired temperature by electric heaters and by throttling.

The extreme conditions above noted permit the reproduction of altitude approximating 30,000 feet.

In the process of cooling the air, a dehumidifying stage is necessary and the air is consequently dry at the carburetor intake, another effect encountered at high altitudes.

The accuracy of the assumption, that altitude conditions as simulated by the method described are identical with actual

altitude conditions, has been checked by the Bureau of Standards so far as engine performance is concerned.

There may be possibility of some errors due to effect of breaking down the dielectric strength of the air surrounding magnetos, spark plugs, etc., when the air surrounding those parts is highly rarified. For practical purposes, however, these errors are so doubtful that they may be disregarded. It is believed that any serious electrical leakage would occur at much higher altitudes than those which we attempt to simulate in the laboratory.

The effect of extreme cold on radiators, both oil and water, is considered as a separate matter from engine performance and on routine tests this is not taken into consideration.

PUMP, STRAINER AND JET TESTING.

For determining the rates of flow under various heads and with different lifts of pumps and for tests in general of strainers, jets, and similar accessories, a steel tower has been constructed, having platforms at 10 feet and 20 feet above the floor level and provision is made for mounting apparatus at any level between platforms.

For carburetor jet flow measurement, a special apparatus has been constructed which measures the flow of water through the jet under a head of one meter. A table showing the standard rates of flow for the various jet sizes is used for comparison.

AIR DYNAMOMETERS.

In order to vary the characteristics of a moulinet or club propeller, it has been found necessary at times to narrow the blades or to attach plates to the same. In order to be able to obtain the same result without alteration to the propeller, a tunnel was devised in which the propeller swings, an opening with a large butterfly valve regulating the amount of air which the propeller can receive.

The air then enters through a belled opening, passes the valve and on being thrown off by the propeller is deflected by a wooden rim, so that it leaves at 180 degrees from its direction at entrance.

A change in the form of valve is under consideration as results of some torque stand tests where this apparatus has been employed have been erratic.

ATMOSPHERIC CONDITIONS.

Engine performance varies with air density. A standard has been adopted and conditions existing at the time of test are carefully noted in order that the results may be reduced to the standard.

Barometers, both aneroid and vertical mercurial, are provided for this purpose and temperature is taken by mercurial or electric thermometers. A wet and dry bulb means of obtaining relative humidity is used when required.

The standard to which correction is made is 29.92 inches of mercury and 59 degrees Fahrenheit. Brake horsepower and brake mean effective pressure are corrected from actual conditions prevailing, directly as the ratio of the barometer readings and inversely as the square root of the ratio of the absolute temperature readings.

SPARK PLUG TESTING.

Electric leakage is determined by means of a 500 volt megger as the temperature of the plug is varied from room temperature to 500 degrees F. in steps of 50 degrees. The same test will be conducted under cold conditions to minus 50 degrees F. when the proper equipment has been completed.

A variable transformer is used to determine the voltage at which the insulation will break down on a spark jump to the shell without breaking down the insulation.

In engine tests the following data are obtained:

(1). Length of time required to foul a plug under various conditions.

(2). Detonation produced under different throttle and spark advance conditions.

(3). Preignition, as shown by continued running of the engine after disconnecting the source of spark, the engine having been previously run under heavy detonation for five minutes.

(4). Ease of starting engine and current, fuel mixture ratio, spark advance, and so forth, for best starting.

(5). Endurance.

Spark plugs are tested for leakage by placing twelve of them in a bomb constructed for the purpose and building up an air pressure of 300 pounds per square inch in the bomb. The plugs are screwed into the shell of this bomb as into an engine combustion chamber. The apparatus is submerged in water and any air leakage through the plugs is collected in inverted graduate glasses. The same method is used, employing hot oil instead of water, for obtaining the amount of leakage under hot plug conditions.

The bomb is fitted with heavy glass ports through which the sparking action of the plugs can be observed under air pressure.

Testing of plugs in a closed bomb in which the air is not changed may be objected to on the ground that the air loses its dielectric strength and becomes ionized, forming an easy path for a low voltage spark between the electrodes, preventing the building up of normal discharge voltage, and for this reason the actual firing test in an engine cylinder is preferred.

By mounting the plug in various positions in a steel block, which is caused to strike a fixed steel block 1000 times per minute at a velocity of 12 foot seconds, the resistance to cracking under vibration and impact is tested. This is followed by an insulation resistance test at certain time intervals.

Plugs having porcelain or similar insulators are heated to a temperature of 300 degrees F. and kept at that temperature while cold water is dropped on the insulator to determine

resistance to cracking, due to change in temperature. After ten hours of this treatment an insulation test is made and the insulators are soaked in eosin, dried and then broken to determine the depth of such cracks as may have developed.

TESTING OF FUELS.

The introduction of engines of high compression ratio precludes the use of commercial gasoline as a fuel, as unblended gasoline will cause detonation to occur under ordinary conditions where the compression ratio exceeds 5.5 :1, with consequent damage to the engine as well as loss of efficiency. Fuel for high compression ratio engines must, therefore, be of such a character as to burn with a proper rate of flame propagation. This is accomplished, practically, by blending gasoline with percentages of such substances as benzol, tetra-ethyl lead or ethyl alcohol, the amounts used depending on the engine.

Certain fuels having anti-detonating qualities have been produced commercially from time to time and the determination of their value as fuels as well as the characteristics of the various blends, form a material part of the work of the laboratory.

Benzol, blended in various proportions with gasoline, forms a convenient index for the measurement of the characteristics of other fuels and has been adopted as a standard.

Bureau of Aeronautics Technical Note No. 134 outlines the method of fuel testing normally followed.

FUELS EMPLOYED.

The fuels used pure or in combination with each other and carried in stock for testing are as follows:—

Gasoline (commercial and aviation); benzol; ethyl alcohol; kerosene; fuel oil distillates; acetone; tetra ethyl lead.

A number of proprietary fuels, blended or processed, are undergoing tests at present. These include:

Stellarene; Cyclogas; Tetralin; Canary Gas; Patentoline.

The relative merits of the various fuels need not be entered into here. The effect in producing power and at the same time suppressing detonation under high compressions is of vital interest at the present time.

Standard methods are employed for determining viscosity, flash and fire point, and specific gravity of fuels and oils.

Further requirements as regards chemical analysis and aniline number or critical temperature of solution, often required in the case of fuels, are usually referred to the Navy Yard chemist, although a small amount of this work can be done with the chemical equipment provided in the instrument laboratory.

A small cup and ball type viscometer is provided for use during tests where the viscosity of oil is required and the Saybolt method would take too much time.

MAGNETO TESTING.

On engines fitted to mount two or more magnetos it is a simple matter to try out two types of magnetos for comparative endurance under the actual conditions of service.

In the laboratory a device for running two magnetos under impact conditions more severe than those of engine vibration is used. With this device variable three point spark gaps are used and performance observed. The oscilliscope is used to observe cam action while running as well as the movement of breakers and other accessible moving parts. An oscillating mirror is employed to observe the character of the spark and by its use the nature of the discharge can be determined with remarkable accuracy.

MISCELLANEOUS TESTING.

A Shore scleroscope furnishes means for testing resiliency of engine parts and a Brinnell machine is used for hardness.

For measurement of wear, clearances, etc., a large surface plate and the necessary gages have been furnished. The preci-

sion instruments, in addition to micrometers and verniers, include a cathetometer for fine measurements of height.

Weights for use on scales and balances and for dynamometer and torque stand calibration are checked on a bullion balance mounted in a glass case and accurate to 2 grains up to 50 pounds. The standard weights for use with this instrument were calibrated at the Bureau of Standards.

Exhaust gas analysis is made by a Hays apparatus which enables determination of CO_2, CO and O content of the gas to be made very quickly. The apparatus is mounted near the engine and a direct tube connection is made to the exhaust outlet to the engine to avoid losses found to occur when the gas was kept with water in aspirator bottles.

TURBO-AIR COMPRESSOR REPAIRS.

By COMMANDER R. L. IRVINE, U. S. N., MEMBER.

The following description of repairs undertaken and completed at the Puget Sound Navy Yard to two turbo-air compressors for the U. S. S. *Nevada* may prove interesting from an engineering viewpoint. These two turbo-air compressors are horizontal, multiple centrifugal pressure staged, direct connected to the motive end, and designed to deliver 2350 cubic feet per minute at 100 pounds pressure. There are thirteen (13) pressure stages, six (6) of which are on one shaft in the low pressure end, and seven (7) on a separate shaft in the high pressure end.

The side discs of practically all stages became badly corroded away near the periphery, causing great loss of efficiency and unbalance and necessitating the renewal of practically all stage wheels. In the stages the impeller elements were corroded to the extent that the scale deposits averaged about 140 mils in thickness over the entire plate surface.

It was considered at first to send these rotors to the manufacturers works for repairs, but this being impracticable and the bids for the manufacture of the necessary parts and proposed delivery dates being greatly in excess of the yard estimate, the Bureau of Engineering directed that the yard perform the work.

When the very accurate dimensions and contours and the thinness of the discs, etc., that were necessary in this work are considered, it is apparent that to produce efficient results very delicate workmanship was required and special methods had to be devised. The plan dimensions are given to thousandths of an inch and these dimensions and the contours of the parts forming the air passages must be strictly adhered to in order to secure efficient operation. The impellers are approximately

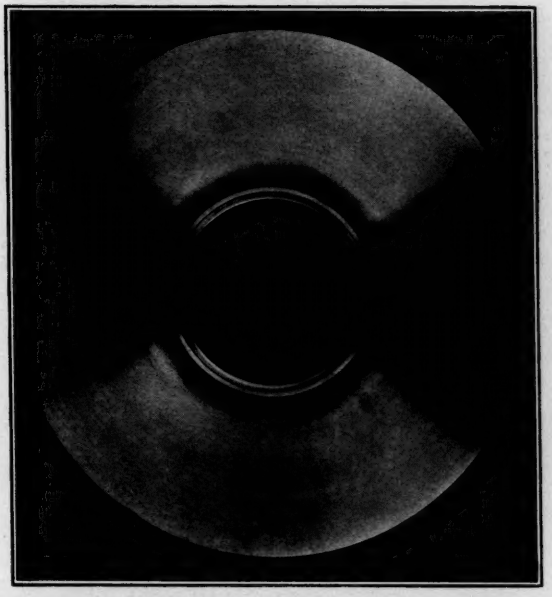


FIG. 1—IMPELLER DISC FINISHED ON BLADE SIDE AND IN BORE.

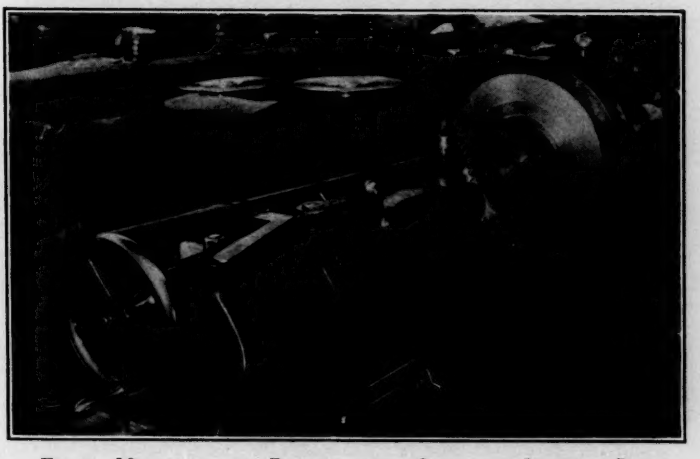


FIG. 2.—MACHINING THE RADIUS ON THE OUTSIDE OF IMPELLER COVER.

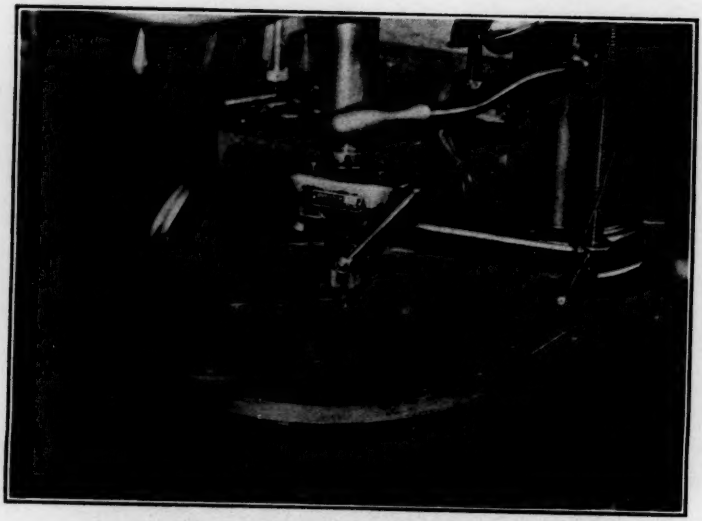


FIG. 3.—BLADE IN THE DRILLING JIG.

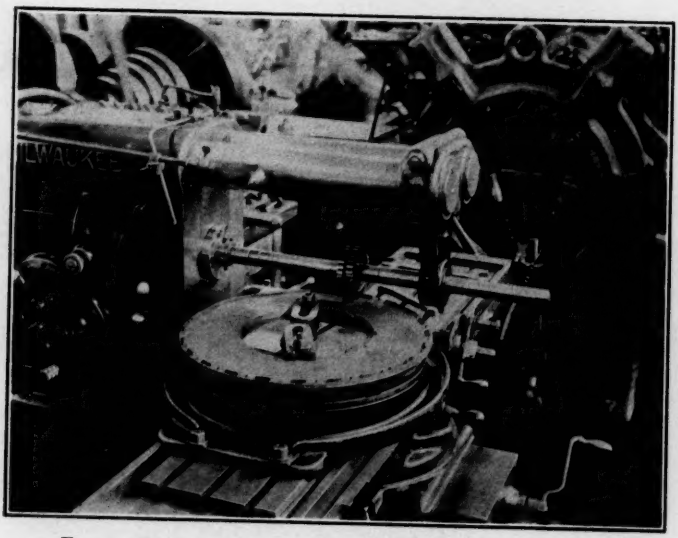


FIG. 4.—ROUGHING OUT THE BLADE AND RIVET OF THE BLADE.

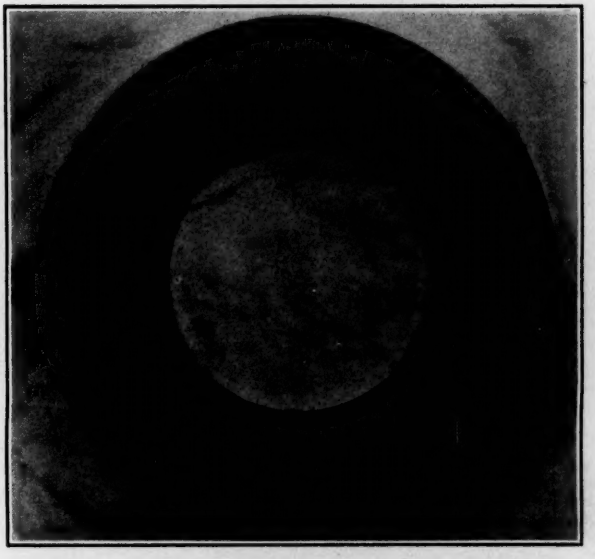


FIG. 5.—LAYING OUT THE BLADE SHAPES.

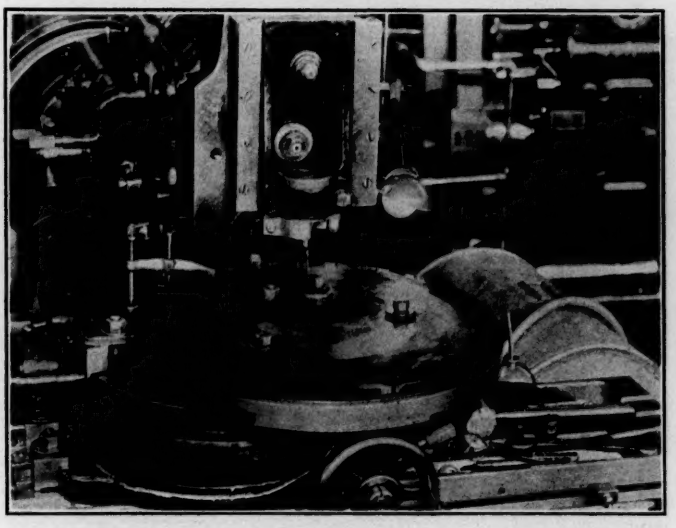


FIG. 6.—SLOTTING OUT ONE SIDE OF THE BLADE.

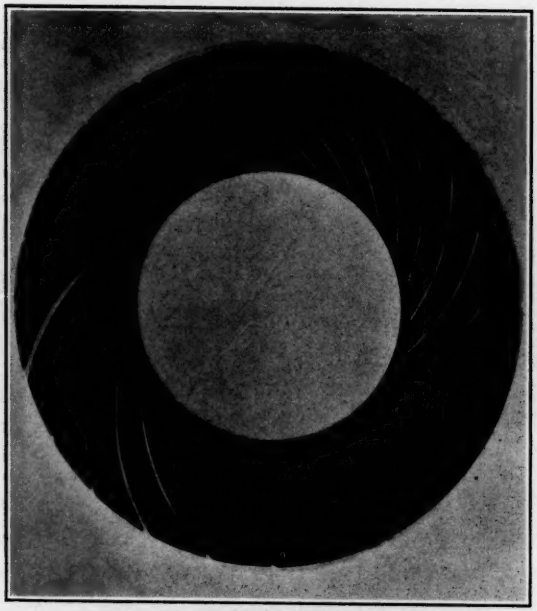


FIG. 7.—BLADE DISC SHOWING BLADES CUT OUT ON ONE SIDE.

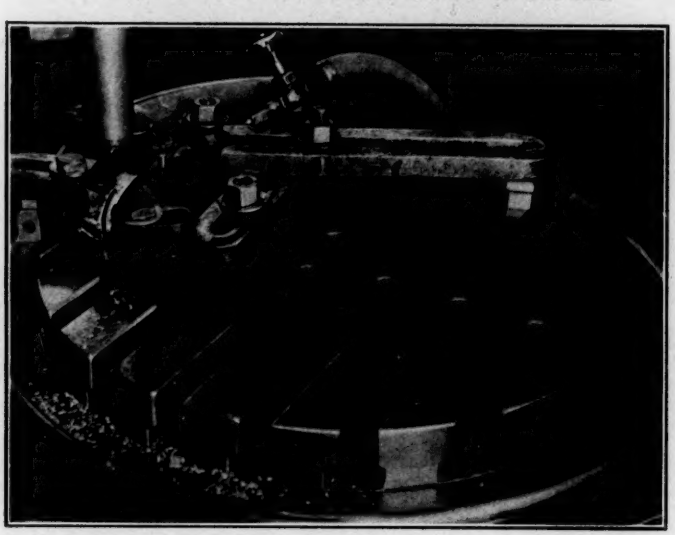


FIG. 8.—FINISHING THE BLADE SHAPES.

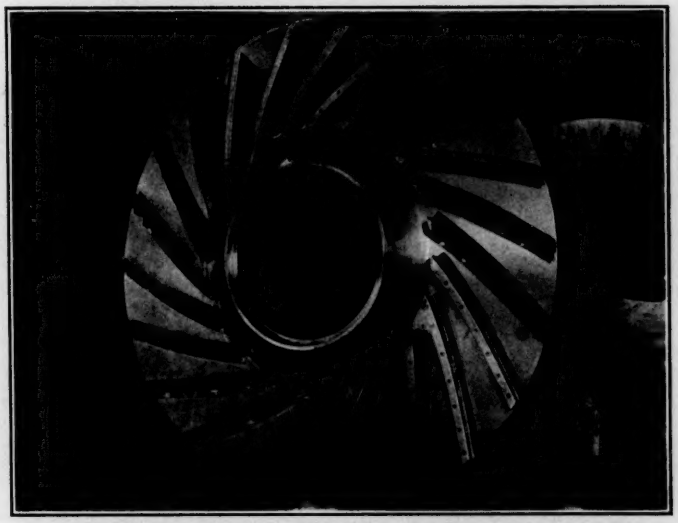


FIG. 9.—Z BAR BLADES RIVETED TO IMPELLER DISC.

FIG. 10.—RIVETING IMPELLER COVER TO Z BARS.

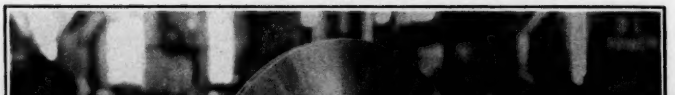


FIG. 11.—A FINISHED IMPELLER.

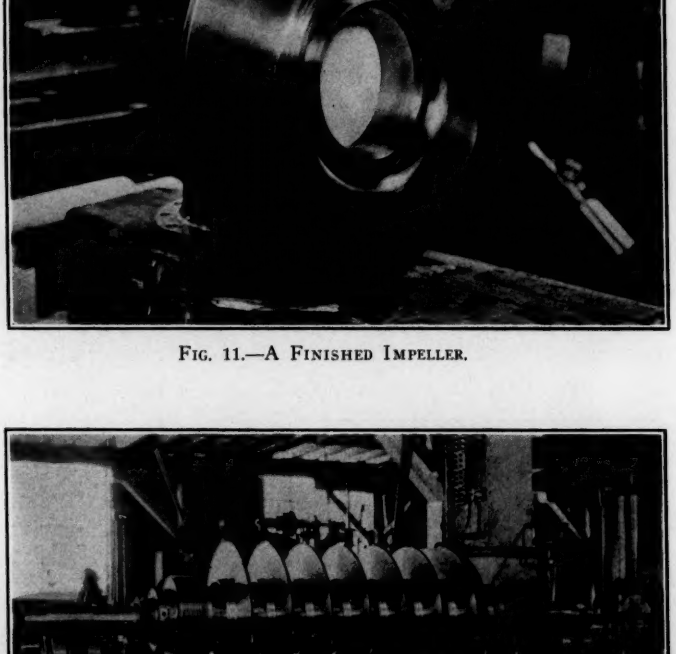


FIG. 12.—THE ASSEMBLED H. P. ROTOR IN THE DYNAMIC BALANCING MACHINE.

21½ inches in diameter, mounted on shafts approximately 7 inches and 7½ inches in diameter. It will be noted that one disc of each impeller is attached to the shaft and the other is carried by attachment to this disc and the vanes by means of rivets in order to provide the air passages which form nozzles within the impellers by means of which the compression of the air is secured through centrifugal force. In order to accomplish this work it was necessary to develop special processes, jigs, dies, etc. The various principal operations are shown in the photographs.

The impeller discs and covers were forged of nickel steel, roughed out to within ⅛ inch of size and then subjected to heat treatment to remove any possible strains. They were then re-chucked and the blade face and bore finished to size, Figure 1. The covers were then bolted in a jig, Figure 2, and the long radius of the outside face finished to within 1/32 inch of size as shown in the photograph. The seals were also finished to within 1/32 inch of size in this operation. The impeller discs were held in a fixture similar to the one used for the covers and the series of angles and radii on the outside face finished to within 1/32 inch of size. Particular care must be exercised in performing this operation to prevent the thin metal of the disc (.059 inch thick at the periphery) from buckling.

Figure 3 shows one of the impeller covers in the drilling jig manufactured from steel plate with a hardened steel bushing in each hole. Three of these jigs, one for each type of blade disc shown on the plan, were required to accomplish this operation.

The Z bar blades or vanes, Figure 9, for the first three stages of the L. P. unit were cut from a sheet of monel metal and formed to shape by a die manufactured for that purpose. The solid blades for the other ten stages were cut from a solid nickel steel forging. The forging was machined on its lateral face to conform exactly with the blade sides of the impeller disc and covers, leaving a flange on either side of sufficient width and depth to make the first rivet at the tip of the blade, Figure 5.

The second operation of roughing out the end rivet was accomplished with a pair of straddle milling cutters, Figure 4. The indexing head of the circular table insured equal spacing which simplified subsequent operations. A hollow mill was used to convert the rivet into its finished state. The blades were then laid out on the finished disc by means of a templet, Figure 5, in the same relative positions that they occupy in the finished impeller.

Figure 6 shows a milling machine slotting attachment at work in cutting out one side of the blade. The position of the holding fixture on the circular table determined the correct radius. A blade disc with this operation completed on 18 blades is shown in Figure 7. Application of power feed to the circular table provided a uniform feed and a very satisfactory cutting speed. The finishing operation on the blade shapes is accomplished in practically the same way with the fixture shown in Figure 8. A small slotter instead of the milling machine was used in this operation. The shape of the solid blades for impellers No. 4 and No. 5 differs from the rest, so the operations of cutting were somewhat varied.

In Figure 10, workmen are shown riveting the blade covers to the Z bar blades. This is a rather difficult operation as the rivets must be inserted from the inside and riveted on the outside. The discs and covers are held securely in place by the close fitting form shown in the photograph. The rivets are inserted with a spring holder shown on the top of the "U" clamp and are held in place by wedges of the proper thickness during the riveting operation. The solid blade impellers are held in the same form but the riveting operation is more simple because through rivets are employed.

When the riveting is completed the impellers are placed on an arbor and finished all over, Figure 11, after which each individual impeller is statically balanced. Figure 12 shows one of the assembled high pressure units in the dynamic balancing machine.

A PROPOSED SOLUTION OF THE DOUBLE ACTING DIESEL ENGINE PROBLEM.

By Captain A. M. Procter, U. S. Navy, Member.

The engine shown in the accompanying sketch is offered as a contribution towards the solution of the problem of designing a double acting, two cycle, engine of large power; suitable for installation in Naval vessels.

The conditions of the problem require that such an engine must have the smallest possible ratio of height to stroke; and that it should be capable of developing the greatest possible mean indicated pressure, at the highest practicable piston speed.

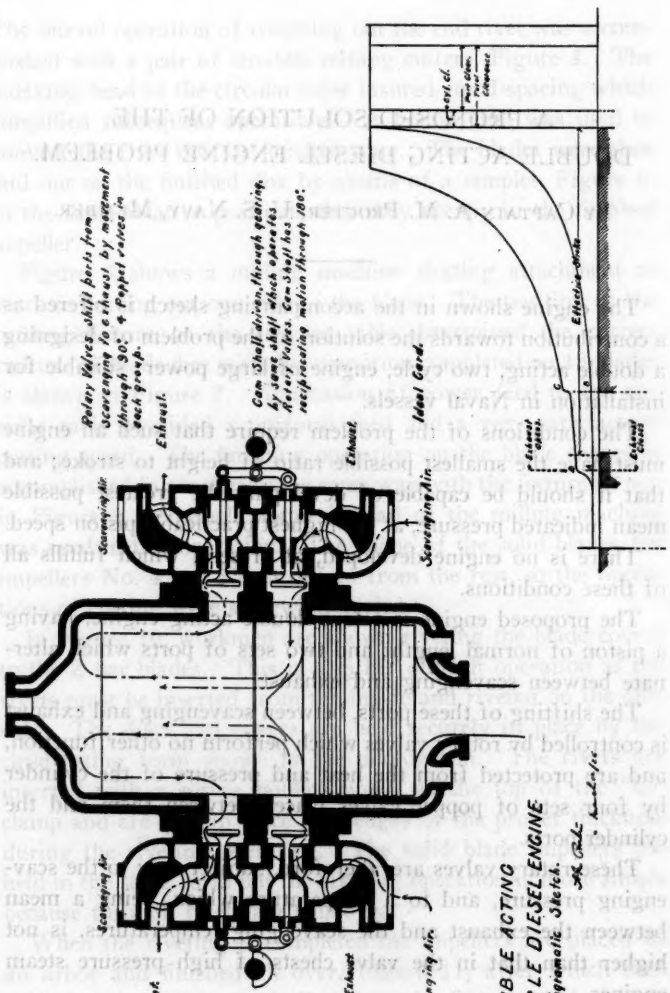
There is no engine developed, at present, which fulfills all of these conditions.

The proposed engine is a true double acting engine, having a piston of normal length; and two sets of ports which alternate between scavenging and exhaust.

The shifting of these ports, between scavenging and exhaust is controlled by rotary valves which perform no other function, and are protected from the heat and pressure of the cylinder by four sets of poppet valves placed between them and the cylinder ports.

These rotary valves are, therefore, subject only to the scavenging pressure, and to a temperature which, being a mean between the exhaust and the scavenging temperatures, is not higher than that in the valve chests of high pressure steam engines.

The working cycle of this engine is shown on the ideal card. At the point A the exhaust is closed and compression into the combined clearance space takes place.


Poppet Valves shift ports from Scavenging to exhaust by movement through 90° + Poppet valves in each group.
Cam Shaft driven through gearing by same shaft which operates Poppet Valves. Cam Shaft has reciprocating motion through 180°.
Ideal Card.
Exhaust.
Scavenging Air.
Exhaust.
Scavenging Air.
Exhaust.
Scavenging Air.
Exhaust.
Scavenging Air.

DOUBLE ACTING 2 CYCLE DIESEL ENGINE
Diagramatic Sketch.

This action is due to the closing of the cam operated poppet valves, and the result is that, at the point B where the port is closed by the piston, there is a materially higher pressure in the cylinder, than would be the case if no poppet valves were fitted.

The effect of this action is to give a materially greater effective stroke with a given length of port.

From the point B compression and expansion are normal to the point C, where the exhaust port is uncovered by the piston.

At this point there will be a drop in pressure, by expansion into the port clearance space, but the useful work card will be continued to the point D where the cylinder is opened to exhaust by the lifting of the poppet valves.

The advantages which might be expected from this engine are as follows:—

1.—A smaller ratio of height to stroke.

2.—A decrease in weight due to the smaller cylinder.

This will be a material gain since the cylinder weights are about one-third the total weights.

3.—Greater accessibility. Examination of the sketch will show that when the piston is on the top center it will be entirely exposed when the upper part of the cylinder is lifted out. It will not be necessary to remove the piston for examination.

4.—Lower temperature in the exhaust passages.

5.—Smaller cylinder castings, and smaller pistons.

6.—A material increase in the mean indicated pressure due to the increase in the length of the effective stroke.

In regard to the disadvantage due to increased complication it may be pointed out that the valve chests will not be larger than the cylinder heads of a four-cycle engine, and will be subjected to a cylinder pressure of but one-tenth of that in that type of engine.

BRUSHES FOR ELECTRIC MOTORS AND GENERATORS.

By W. E. Stine, Assistant Material Engineer, Navy Yard, New York.

Brushes for use on motor and generator commutators and sliprings may be classified in a classification according to their composition and construction as follows:

(*a*) Copper leaf.
(*b*) Metal gauze.
(*c*) Metal-graphite.
(*d*) Graphite.
(*e*) Carbon-graphite.
(*f*) Electro-graphitic or Graphitized carbon.
(*g*) Carbon.

The copper leaf brushes are constructed of very thin copper leaves. Several years ago, these brushes were used quite extensively on sliprings and very low voltage generators.

The copper gauze brushes are made up of several layers of fine mesh copper gauze pressed together. These brushes have the same use and limitations as the copper leaf brushes.

The copper leaf and copper gauze brushes have practically been superseded by the metal-graphite brushes. The metal-graphite brushes have the advantage of lower friction and that by varying the percentage of graphite, the contact drop can be varied to cover a range of from a very small value up to the value obtained with pure graphite brushes. It has been found that contact drop plays an important part in the operation of brushes on commutators. This will be discussed in a later paragraph. Metal-graphite brushes consist of a mixture

of metal and graphite moulded into the desired form. The metal usually used is copper, although other metals are sometimes used. The use of metal-graphite brushes is usually limited to sliprings and low voltage generators.

Graphite brushes usually consist of natural graphite and a small amount of some kind of binder pressed or moulded into the desired form. Sometimes the graphite is furnished in blocks from which the individual brushes may be cut. The characteristics of pure graphite brushes are low friction and medium contact drop.

Carbon-graphite brushes consist of a mixture of carbon and graphite. This mixture results in a brush somewhat harder and stronger than a pure graphite brush. The contact drop is also higher. The percentage of graphite is varied to produce brushes of different operating characteristics.

Electro-graphitic or graphitized carbon brushes consist of pure carbon fired at a high temperature which gives it some characteristics similar to pure graphite while retaining some of the characteristics of carbon. The method of preparation and manufacture determine its characteristics which can be varied over a wide range.

Carbon brushes usually consist of carbon to which may be added an abrasive material or a lubricant. The usual characteristics are high specific resistance, comparatively high friction, and high contact drop which give it a comparatively low current carrying capacity.

Under each of the above described classes of brushes, there are many grades on the market. It has been estimated that there are several hundred grades of brushes manufactured in hundreds of styles, shapes and dimensions. Under such conditions, it is very difficult to draw up specifications for open purchase in such manner that the Navy is assured that all material proposed will be suitable for the intended purpose.

The importance of selecting the proper brushes for replacements on motors and generators cannot be over-estimated.

While a new set of brushes may cost only a few dollars, a set having the wrong characteristics may place a motor or generator costing several hundred dollars in the repair shop, within a short time, and result in the expenditure of many times the cost of the brushes for repairs.

When a new motor or generator is purchased from the manufacturer, tested and inspected by the Government's representative, it is reasonable to assume that the brushes supplied by the manufacturer of the machine will be satisfactory under all normal conditions of operation on shipboard. Therefore, it is evident that if the brushes purchased for replacement are of the same grade as originally furnished, no new difficulties with the commutation of the machine will be experienced after the installation of the new brushes. It has been the experience, that the only way to be sure that the new brushes will be the same grade as originally furnished, is to purchase all brushes, for replacements, from the manufacturer of the motor or generator. This procedure appears to be the most satisfactory, when practicable, and the most economical in the long run.

When brushes are not purchased direct from the manufacturer of the motor or generator, it is usually necessary to purchase the brushes or brush material under specifications giving limits within which certain physical and electrical characteristics must come. These characteristics can only be determined by test.

PHYSICAL CHARACTERISTICS.

The physical characteristics of brush material which can be determined by test are as follows:

(*a*) Hardness.
(*b*) Specific resistance.
(*c*) Transverse strength.
(*d*) Coefficient of friction.
(*e*) Contact drop.

(*f*) Maximum peripheral speed.
(*g*) Current carrying capacity.
(*h*) Percentage of ash.
(*i*) Impurities.

The method of conducting the tests and the interpretation of the results in terms of operation under actual conditions is somewhat difficult and cannot always be done. A discussion of these points follows:

Hardness is determined by means of a Shore scleroscope. Readings are taken on all sides of the sample. The uniformity of the readings is an indication of uniformity of texture. The hardness of a brush is no important indication of its actual operating characteristics. The determination of the hardness serves chiefly as a check on uniformity of manufacture and as a means for classifying the material.

The specific resistance is the resistance of a one inch cube and is determined by measuring the resistance of a given length of the material of uniform rectangular cross section and is calculated by use of the following formula:

$$\text{Specific Resistance} = \frac{EWT}{IL}$$

where E is the drop in volts over the length L when the current I is flowing through the test piece, I is the current in ampères, W and T are the width and thickness, respectively, in inches and L is given in inches. Some brushes are moulded in layers to produce higher resistance across the thickness of the brush than lengthwise. In such cases the specific resistance should be measured in both directions. The effect of the resistance in the body of the brush on the flow of current in the armature coil, short circuited by the brush, is negligible compared to the effect of the contact resistance. The specific resistance and temperature coefficient of resistance are useful in predicting the contact drop as well as checking uniformity of manufacture.

The transverse strength is obtained by breaking a test piece of uniform rectangular shape. The piece under test is supported on two dull knife edges and pressure is applied on a third dull knife edge midway between the two supports until the test piece breaks. The transverse strength or "Modulus of Rupture," is calculated from the formula:

$$\text{Transverse Strength} = \frac{3PL}{2WT^2}$$

Where P = Pressure in pounds.
W = Width of piece in inches.
T = Depth of piece in inches.
L = Distance between supporting knife edges.

The pressure must be applied gradually through some resilient medium such as a spring. The depth of the test piece should never exceed the width. The transverse strength of a brush is an indication of the resistance of the brush to chipping.

Accurate values of coefficient of friction are difficult to determine. The coefficient of friction will be one value when the commutator is clean and bright and another when the commutator becomes blackened due to deposits of the brush material on the commutator. The first represents the coefficient of friction of the brush on copper and the second represents the coefficient of friction of the brush on the brush material. Under service condition the coefficient of friction may be anywhere between these extreme values. It is important that there be no "chattering" of the brushes during the tests. Since brush friction is one of the principal sources of brush loss and producer of heat, it is one of the factors which limit the current capacity of the brush.

Contact drop is usually expressed in volts, positive plus negative, *i. e.*, volts drop at the contact of the positive brush plus the volts drop at the contact of the negative brush. The contact drop at the negative brush is usually greater than at

the positive brush. While the contact drop varies with the current, it is not proportional to the current. Figure 1 is a typical contact drop curve. Contact drop is a very important and useful factor in the operation of brushes on commutators because the short circuit current in the armature coil short

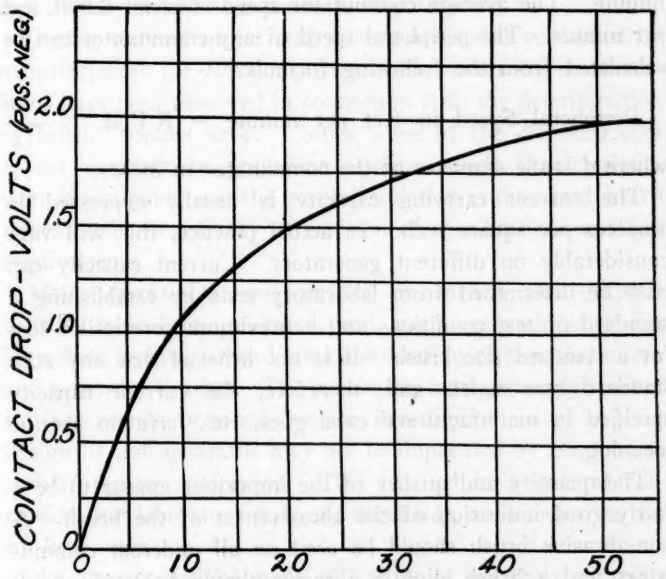


FIGURE 1

circuited by the brushes must pass from the commutator to the brush and then from the brush back to the commutator. Thus the positive plus negative contact resistance is always in series with the short circuited armature coil. This contact resistance is many times more effective in limiting the short circuit current in the short circuited armature coil than the resistance of the brush material. The contact drop loss is a large per-

centage of the total brush losses and, therefore, is one of the principal factors which limit the current capacity of the brush.

Maximum peripheral speed must be known in order that the maximum friction losses can be calculated. Very few, if any, commutators on shipboard exceed 4,500 feet per minute. The average commutator speed is about 2,000 feet per minute. The peripheral speed of any commutator can be calculated from the following formula:

$$\text{Peripheral Speed in feet per minute} = \text{R.P.M.} \times \frac{\pi d}{12}$$

where d is the diameter of the commutator in inches.

The current carrying capacity is usually expressed in ampères per square inch. In actual practice, this will vary considerably on different generators. Current capacity can only be determined from laboratory tests by establishing a standard of test conditions and a maximum permissible loss for a standard size brush. It is not believed that any such standard now exists and, therefore, the current capacity specified in manufacturers' catalogues, etc., have no specific meaning.

The quantity and quality of the impurities appear to be a fairly good indication of the abrasiveness of the brush. A non-abrasive brush should be used on all undercut commutators and a brush slightly abrasive should be used on all commutators having flush mica.

The abrasive action of a brush can be divided into two classes. The one is the natural mechanical abrasiveness of the brush material and is effective whether the brush is carrying current or not. This action is desirable only for wearing down mica on commutators with flush mica. The other abrasive action is present only when current is flowing and is executed only by the negative brush. This action appears to be by particles of copper becoming electrically welded to metallic impurities in the brush. Small particles of the com-

mutator are pulled loose in this manner. This action is undesirable and should be avoided by using brushes as free from metallic impurities as possible.

It is understood that British manufacturers have standardized on 12 different sizes of brushes and adopted a standard type of brush holder. Similar action by manufacturers in this country would be a desirable step forward.

During tests of motor and generator brushes submitted by manufacturers for Navy approval, some interesting characteristics have been observed in connection with the determination of brush "contact drop." Since some of the characteristics appear contrary to prevailing opinion, these characteristics were investigated and the general situation is discussed which indicates the desirability of revision of specifications and test requirements.

Many discussions and articles on carbon and graphite brushes have been published, and much research work has been done looking toward a standardization of tests for motor and generator brushes. The conclusion most generally reached is, that results obtained by one investigator using a given design of test apparatus may not be duplicated by another, on similar testing equipment. This has led to a general conclusion that laboratory tests are unreliable, not conclusive, and of little value.

An attempt will be made (1) to point out the desirability of standardized laboratory tests, (2) to point out the relative importance of contact resistance, (3) to show that an erroneous assumption is generally made for the basis of tests, (4) to show that when based upon correct principles, data obtained from tests carefully conducted are reliable and consistent, and (5) to show that a correct understanding of contact resistance would result in the universal use of an increased number of brushes of very small cross-sectional dimensions which would then logically result in the universal use of only a few standardized sizes, and grades.

DESIRABILITY OF STANDARDIZED TESTS.

The general practice of manufacturers and users of brushes is to rely almost wholly on service tests to determine the suitability of a given grade of brush for a certain class of service. The conditions of the service tests are not subject to control. The commutators of commercial machines vary considerably in roughness and eccentricity. It has been found that an eccentricity of only .0005 inch in a 10 inch diameter commutator, affects materially the determinations of contact drop and coefficient of friction at usual commutator speeds.

The testing of new grades of brushes on machines in service, is not good practice from an economical point of view. The test may result in excessive wear or damage to an expensive machine. From an engineering point of view, this method of testing brushes is unsatisfactory. In order to progressively develop carbon brushes it is highly desirable that operating characteristics be determined from laboratory or factory tests.

Lack of standardized laboratory tests, and the dependence placed upon operating tests under undefined service conditions probably account for the great variety of grades on the market and the frequency of withdrawal of old grades and the appearance of new grades. Standardized laboratory tests form the only logical basis for comparing brushes of different manufacture.

RELATIVE IMPORTANCE OF CONTACT RESISTANCE.

When two electrical conductors are brought in contact with each other for the purpose of conducting an electrical current, a resistance is offered to the flow of current at the point of contact. When the two conductors consist of a brush and a commutator or collector ring, the resistance of the contact is not usually given in ohms but is indicated only by stating the volts drop, measured across the contact with normal cur-

rent flowing. We therefore, have become accustomed to speak of "brush contact drop" instead of "brush contact resistance."

Contact resistance plays an important part in the successful operation of modern commercial carbon and graphite brushes. Brushes having comparatively high contact resistance have been found of value in limiting the short circuit current in the armature coils of a commutating machine. Practically all of the resistance to the flow of this current through commercial brushes is offered at the point of contact. Since this short circuit current must flow through two contact resistances on the same brush, the "positive contact drop" plus the "negative

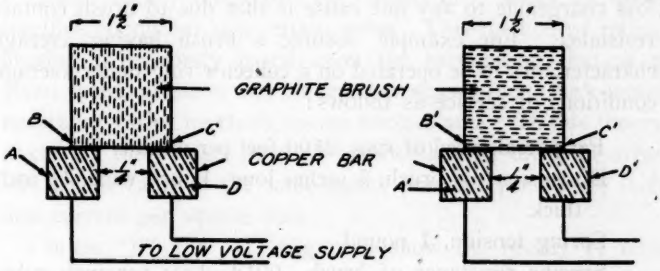


FIG. 2 (a)
AMPS. = 5
VOLTS A to D = 0.8
VOLTS B to C = 0.027

FIG. 2 (b)
AMPS. = 5
VOLTS A' to D' = 1.0
VOLTS B' to C' = 0.025

contact drop" as determined on a slip ring or test machine, is considered to be an indication of the resistance of the brush to the flow of short circuit current in the armature coils.

In order to determine the relative effect of the contact resistance and the resistance of the material in the body of the brush in limiting the short circuit current in the armature coil short circuited by the brush, a simple test as shown in Figure 2(*a*) and 2(*b*) was made. With a current of 5

ampères 96.6 per cent of the voltage drop in the brush was at the points of contact, and only 3.4 per cent was in the body of the brush.

The resistance offered at the point of contact to the flow of the line current from brush to the commutator or collector ring, and *vice versa,* results in loss of useful power, lowers the machine efficiency and increases the operating temperature. It therefore follows that the contact resistance of brushes for use on commutating machines should be only sufficiently high to limit the short circuit currents in the armature coils to desired or reasonable values.

An analysis of the commutation losses when using commercial carbon or graphite brushes, will show that the largest loss chargeable to any one cause is that due to brush contact resistance. For example, assume a brush having average characteristics to be operated on a collector ring under average conditions of service as follows:

Peripheral speed of ring, 2500 feet per minute.
Dimensions of brush, 2 inches long, 1 inch wide, ½ inch thick.
Spring tension, 1 pound.
Specific resistance of brush, .0012 ohms per inch cube.
Coefficient of friction .25.
Current per brush 20 ampères.
Contact drop 1 volt.
Volts drop from brush to flexible lead .01 volts.

The losses will then be as follows:

		Watts	*Per Cent*
I^2R loss in body of brush	=	1.92	5.3
Loss in flexible lead connection	=	0.20	0.6
Friction loss, equivalent to	=	14.10	39.0
Contact loss	=	20.00	55.1
Total losses, equivalent to		36.22	100.

When operating on a commutator, the contact loss will be increased due to the flow of the short circuit current through the brush.

If current ratings of brushes are to be determined by laboratory test it will be necessary to understand the nature of the contact resistance and be able to determine it accurately.

CONTACT RESISTANCE DOES NOT VARY INVERSELY AS THE AREA OF CONTACT.

The general practice of many brush manufacturers is to rate brush material in ampères per square inch at a stated commutator speed and pressure per square inch of contact area. It is also usually stated that the contact drop under the same specified conditions is a certain value. This method of rating brushes is evidently based upon the assumption that at a given speed, pressure and current per square inch, the contact resistance varies inversely as the contact area. If this theory is correct the contact drop of brushes having different areas will be the same at the same speed, pressure per square inch and current per square inch.

Curves "B" and "C" Figure 3 show the results of tests made to check the correctness of the above theory. The data were obtained on a 50 K.W. generator which had been in service for some time. The commutator, however, was in good condition. For the purpose of the tests the residual magnetism was reduced to zero and current was circulated only through the brushes and armature from an external source. The brushes used were the brushes supplied with the machine and only two brushes were used at a time. The commutator speed was maintained at 500 feet per minute. The contact drop, positive plus negative, was considered to be the voltage drop from the toe of the negative brush to the toe of the positive brush minus the voltage drop in the armature. The method by which the area of the brush was reduced is shown in Figure 5.

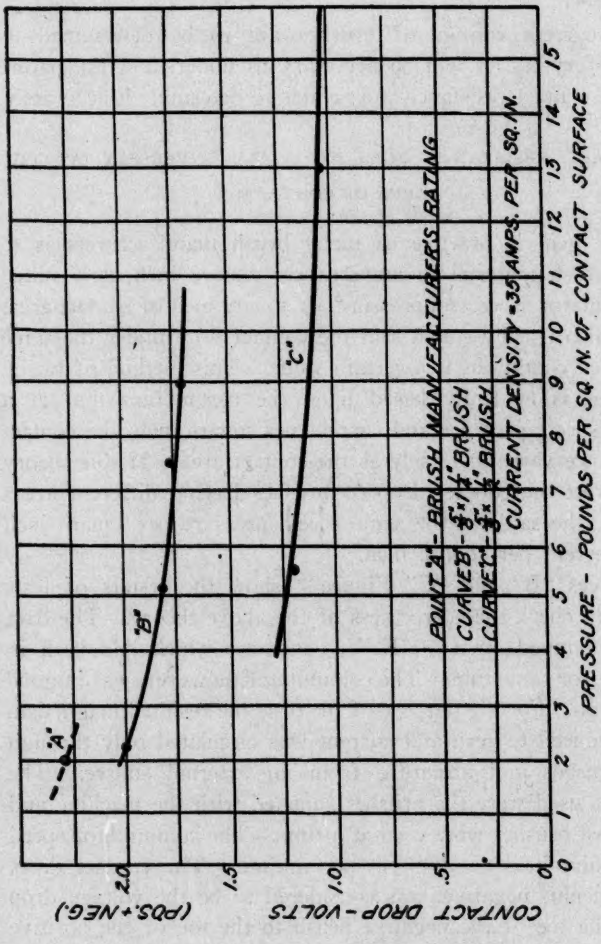

CONTACT DROP - VOLTS (POS.+NEG.)
2.0
1.5
1.0
.5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
PRESSURE - POUNDS PER SQ IN. OF CONTACT SURFACE
POINT 'A' - BRUSH MANUFACTURER'S RATING
CURVE 'B' - 3/4" x 1" BRUSH
CURVE 'C' - 3/4" x 1" BRUSH
CURRENT DENSITY = 35 AMPS. PER SQ. IN.
'A'
'B'
'C'

FIG. 3.

If the above theory had been correct all points on curves "A," "B" and "C" would have fallen on one curve. It therefore follows that when based on the present generally accepted theory, measurements of contact drop cannot be duplicated unless always measured on the same size of brush.

CONTACT RESISTANCE IS INDEPENDENT OF THE CONTACT AREA

Contact resistance is not determined by the area involved although prevailing opinion appears to be to the contrary. A considerable number of tests have been made to determine what factors influence contact resistance between two conductors. (See article on "Electrical Contact Resistance" by F. W. Harris in the Electric Journal for July, 1913, P. 637; Also Article on "Contact Resistance of Large Conductors" by Arne R. Enger in Electric Journal of July, 1924, P. 316.) As a result of these tests the following laws were outlined:

"1—All other conditions being constant, the voltage across a contact joint will increase directly with the current, or the joint between two materials behaves exactly like a resistance.

"2—Where the conditions of the surfaces in contact are not affected thereby, the voltage across the contact will vary inversely with the pressure.

"3—The resistance between the materials depends directly on the internal resistance of the materials, those having a low resistance having also a low contact resistance.

"4—The resistance between contacts depends not upon their area but only on the total pressure with which they are forced together."

Before attempting to apply these laws to brush contact resistance, the mechanical nature of the contact should be thoroughly understood. The theory upon which the above laws are based is that the contact under light pressure will be at three points and that as the force pressing the conductors together

is increased these small areas of contact, by a process of breaking down, or bending, will increase in size and number. This theory has been referred to as the "three point contact theory."

This theory can be easily understood when the surfaces are rough and irregular, as the points of contacts can be observed without the use of a microscope. However, the same thing applies to comparatively smooth surfaces even though the greater part of the surfaces may be separated by only a few one hundred thousandths of an inch.

It appears as though the investigations from the results of which the above laws were formulated, covered stationary contacts. However, it can be shown that in general they apply equally well to brush contact resistance.

The contact between moving or sliding conductors at any instant of time will be the same as for stationary conductors. It is, however, to be expected that after the conductors or brushes have become thoroughly "worn in," the contacts will shift rapidly from place to place over the contact surface of the conductor or brush. In all other respects they will behave exactly like stationary conductors.

Because of the hardness of the material and the comparatively light pressure used on carbon brushes, it is doubtful if the average number of "contact points" in contact with the commutator is ever very great, especially when held in a box type brush holder. In this connection it should be remembered that few commercial commutators are perfectly round and that each part of the commutator is worn or ground away by more than one brush. Therefore no one brush is ever ground to a "perfect fit."

From the foregoing it will be seen that there are only a very few points of very small area in contact with the commutator at any one time and when the commutator is standing still all the current from commutator to brush or *vice versa* must pass through these very small conducting portions. Now, when the commutator begins to move, some of these contacts are broken and new contacts are formed at other parts of the surface. It

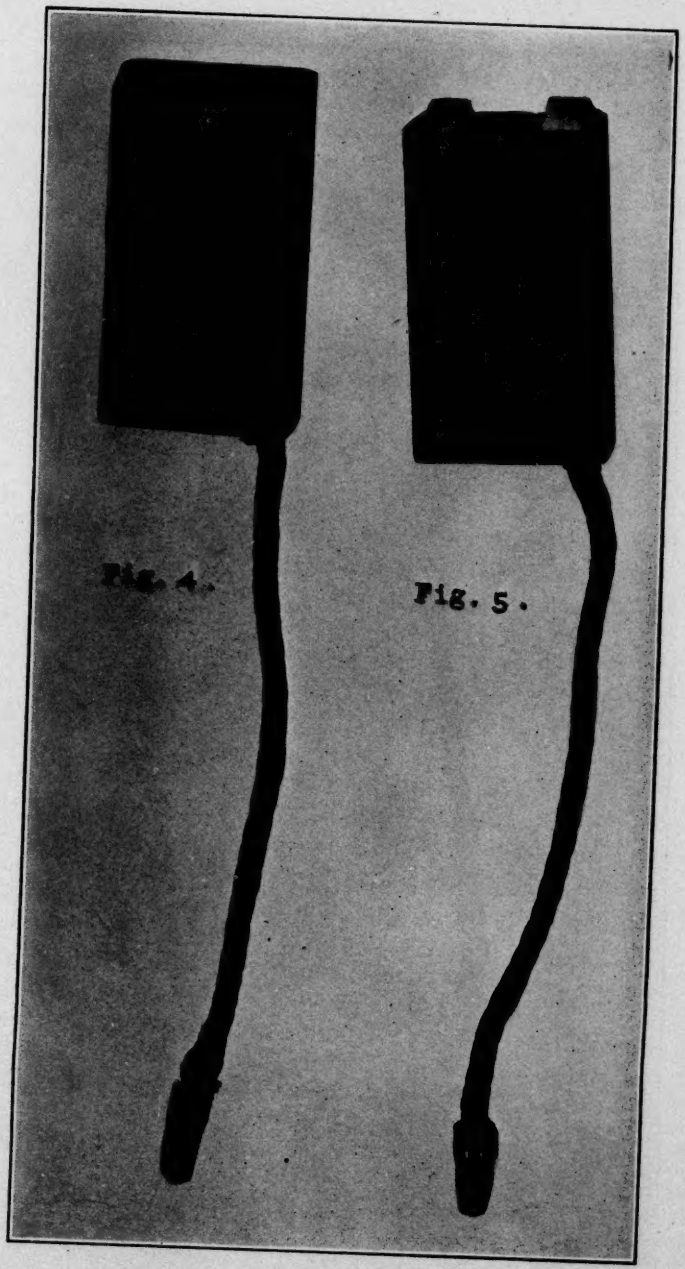


Fig. 4.

Fig. 5.

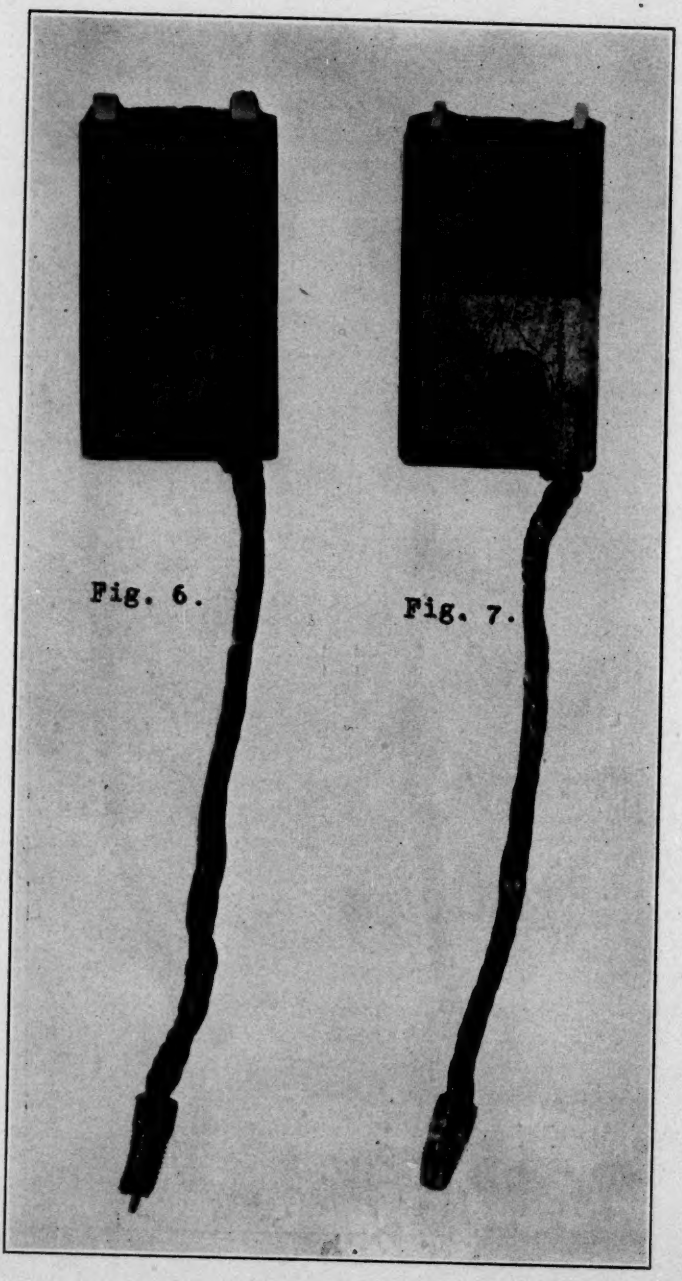


Fig. 6.

Fig. 7.

will be assumed that as the contact points are broken, small arcs are formed for a very short interval of time. These arcs are in parallel with the other solid conductors. The percentage of current following through the arcs under normal conditions is usually very small. We therefore in studying contact resistance will confine the discussion principally to the solid material forming the contact.

In applying the first law, given above, to brush contact resistance, it should be remembered that carbon and graphite material have a negative temperature coefficient of resistance, and that therefore the resistance will decrease as the current is increased due to the higher temperature. The contact drop, therefore, will not increase in direct proportion to the current. The resistance of the small arcs in parallel with the solid conducting material also have the same characteristics.

It is believed that no one will question the correctness of the second law if interpreted to mean that the voltage drop decreases when the brush pressure increases.

Carbon and graphite have from 200 to 400 times the resistance of copper. If the third law is true, practically all resistance at the contact will be in the brush and according to the "three point contact theory" this resistance is at the face of the brush. It therefore can be assumed that practically all the heat produced by the contact resistance is produced in the material within .01 inch from the face of the brush. The expenditure of such an amount of electrical energy in such a small amount of material probably heats the material forming the "point contacts" to a rather high temperature.

It has been noted that the contact drop at the positive brush is less than the contact drop at the negative brush. This, at first thought, may seem to be contrary to the third law. However, this phenomenon appears to be the result of two causes working together. One is thermal-electric, and the other is that, due to arcing, the material in the face of the positive brush is brought to a higher temperature than the material in

the face of the negative brush. It will be recalled that the positive electrode of an arc becomes hotter than the negative. Since carbon has a negative temperature coefficient of resistance, the positive brush which has a higher temperature, will have a lower contact resistance.

The fourth law stated above presents probably the most striking contrast to prevailing opinion. This law is based upon

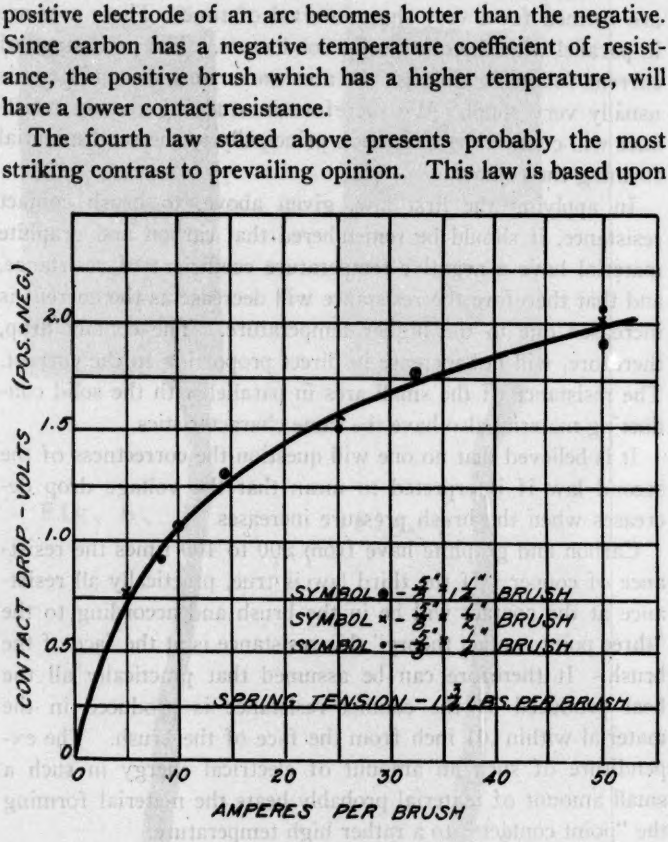


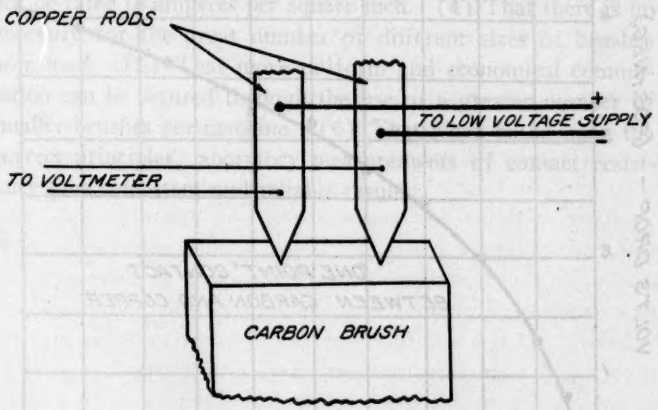
FIG. 8.

the "three point contact theory." In order to check the correctness of this law when applied to brush contact resistance, tests were made on two brushes under the conditions previously described in this paper except that the pressure was maintained constant and the contact drop was measured for different values of current. Three sets of readings were taken. The first set

was taken on brushes having a contact surface 5/8 inch × 1¼ inches. The second was taken on the same brushes with the contact surface reduced to 5/8 inch × ½ inch and a third set was taken on the same brushes with the contact surface reduced to 5/8 inch × ¼ inch.

The manner in which the contact surface was reduced is shown in Figures 5, 6 and 7. The current was maintained constant for one-half hour before each reading was taken. The results of these tests are shown plotted in Figure 8.

Figure 8 shows that, although the contact surface of the brushes was reduced to ⅛ of the original values, all the values



ONE POINT CONTACT BETWEEN CARBON AND COPPER
PRESSURE PER CONTACT = ½ LB.

FIG. 9.

of contact drop fall on the same curve, and that for the same values of current the contact drop was independent of the area. This result cannot be explained on the basis of the accompanying increase of pressure per square inch of contact surface, as Figure 3 curve "B" shows that a 500 per cent increase in pressure per square inch (from 2 to 10 pounds) produced only

16 per cent decrease in contact drop (from 2.02 to 1.70 volts). It therefore appears that all other things being constant, the contact resistance of brushes is independent of the area of the contact surface of the brush.

Two brushes having contact surfaces 5/8 inch × 1/8 inch as shown in Figure 7 were operated continuously carrying 50 ampères per brush, which is 640 ampères per square inch of

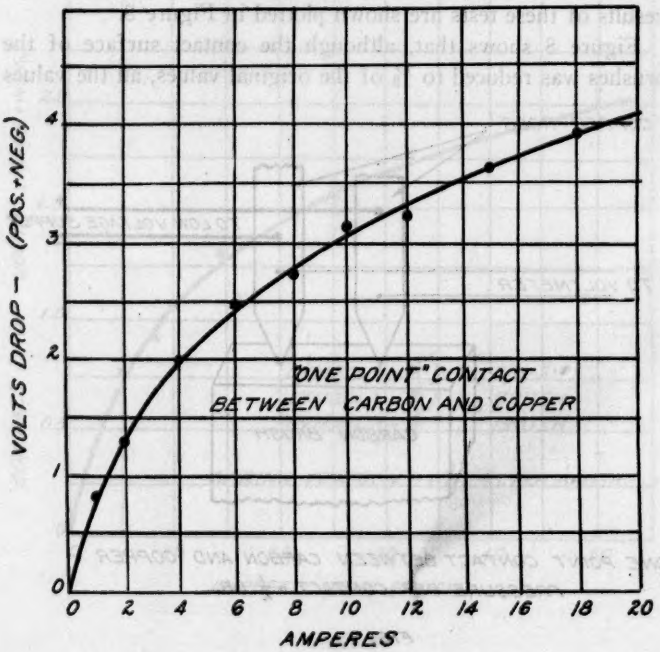


FIG. 10.

contact surface. The brushes under such conditions operated equally as well as similar brushes carrying the same current per brush but having 10 times the contact surface.

Figure 10 shows a contact drop curve for a "one point con-

tact." This curve shows the contact drop, positive plus negative, of a point contact between pointed copper rods, and a carbon brush as shown in Figure 9. It will be noted that the shape of this curve is similar to an ordinary brush drop curve.

CONCLUSION.

The results of these tests show: (1) That there is need for a new basis for rating brush material. (2) That brush contact resistance is independent of the area of contact surface. (3) That, in view of the fact that approximately one-half of the total brush loss is contact drop loss, brush material should not be rated in ampères per square inch. (4) That there is no necessity for the great number of different sizes of brushes now used. (5) That more uniform and economical commutation can be secured through the use of a greater number of smaller brushes per machine. (6) That when based upon the correct principles, laboratory measurements of contact resistance give consistent and reliable results.

THE SCREW PROPELLER AS AN AID TO NAVIGATION.*

By Rear Admiral C. W. Dyson, U. S. Navy, Member.

The revolutions of any given propeller driving any given hull at any particular speed over the water are dependent upon the submerged lines of the after body of the hull; upon the resistance of the hull at the given speed; and upon the pitch, diameter and projected area of the propeller.

The revolutions of the same propeller for any given speed over the bottom of the sea will, in addition to the above, be affected by the velocity of flow of the ocean current in which the vessel is steaming, by the force and direction of the wind and sea, and by the degree of foulness of the ship's bottom.

By analysis of any given service performance of a propeller, compared with its performance over the measured mile, the performances being practically at the same displacements, it is practicable to differentiate between the effect of ocean current upon speed of ship and the combined effect of wind, send or retardation of sea, and foul bottom and to compute the amount of each with a fair degree of accuracy, far superior in accuracy to the present means employed in the navigation of vessels when correcting the run of a ship for these factors.

To illustrate, we will take the case of the Light Cruiser *Richmond* steaming in still water at a speed of 20 knots for which a shaft horsepower of 12,800 and revolutions of 186 are required, the displacement being 9200 tons, then this ship, with the same power and displacement, steaming in the open sea at varying speeds over the bottom, and, by analyses of the two conditions, determine how much of the difference in speed is produced by ocean currents and how much by the combined effect of wind, send or retardation of the sea and foulness of the ship's bottom.

* Reference: Dyson's "Screw Propellers," 3rd edition.

The first step necessary to take is to establish the basic condition of the propellers and the propeller loss due to hull form, also the basic slip for the hull from an analysis of the still water performance as determined over the measured mile. (See Ref., Chapter on Analyses of Performances.)

ANALYSIS OF THE PROPELLER FOR BASIC POWERS.

Diameter	D	11′.33
Pitch	P	12′.0
Projected Area Ratio	$\frac{P.A.}{D.A.}$	.609
No. of Blades	N	3
No. of Propellers	n	4
Basic Tip Speed	T.S.	13,800
Basic Shaft Trust per square inch of disc area	$S.T._d$	11.4
Basic Shaft Horsepower	S.H.P.	93,328
Basic Shaft Prop. Coef	$P.C._s$	.572
Basic Effective Horsepower	E.H.P.	53,384
To find value of Loss Factor K at 20 knots.		
Shaft Horsepower for 20 knots =	$S.H.P._d$	12,800
Z_s = Log S.H.P. − Log	$S.H.P._d$	—.8628
Effective horsepower for 20 knots, Model Tank =	*e.h.p.*	= 7,700
e.h.p. ÷ E.H.P. = 7700 ÷ 53,384		.1442
Z_p for *e.h.p.* ÷ E.H.P.		—.8757
Log K = $Z_p - Z_s$		.0129
K		1.03

TO FIND BASIC SLIP S.

Actual value of 1 − apparent slip = $\frac{20 \times 101.33}{12 \times 186}$ = .908

Actual apparent slip = s = .092

Assume S = .075, .10, .125, .15, .175, .20, .225, .25

Basic Speeds corresponding to these values of S are Equal to $\{T.S. \times P \times (1-S)\} \div \{\pi \times D \times 101.33\}$

$$\text{V for } \begin{cases} S = .075 \ldots = 42.47 \\ S = .10 \ldots = 41.32 \\ S. = .125 \ldots = 40.18 \\ S = .15 \ldots = 39.03 \\ S = .175 \ldots = 37.88 \\ S = .20 \ldots = 36.65 \\ S = .225 \ldots = 35.58 \\ S = .25 \ldots = 34.44 \end{cases} \text{; and } \frac{v}{V} = \frac{20}{V} = \begin{cases} .4709 \\ .484 \\ .4978 \\ .5125 \\ .528 \\ .5458 \\ .5621 \\ .5808 \end{cases} \text{ and Z for } \frac{v}{V} \begin{cases} .860 \\ .83 \\ .803 \\ .76 \\ .72 \\ .68 \\ .641 \\ .601 \end{cases}$$

$$\text{S for these values of } Z_s = S\frac{10^{x_s}}{10^x g} = \begin{cases} .07542 \\ .09273 \\ .1089 \\ .1184 \\ .1260 \\ .1313 \\ .135 \\ .1368 \end{cases}$$

Laying down a curve of S from the above data on values of S as abscissas, we find that, for $s = .092$, the corresponding Basic S = .0985. Figure 1.

Values of S should be worked out for a series of speeds at this and several other displacements for which Model Tank curves of resistance and Standard mile curves of performance have been obtained, and curves of S for these different displacements laid down on knots speed as abscissas.

Turning now to the ocean performances, we will assume an arbitrary series of speeds, shaft horsepowers and revolutions and will deduce from the corresponding speeds of current, direction of current as to whether with or against the direction of travel of the ship, and the combined effect of wind, sea and condition of ship's bottom in its tending to increase or decrease the speed of the vessel.

Let us therefore assume that

v = Speed of ship over bottom in knots

19 19.25 19.5 19.75 20 20.25 20.5 20.75 21.

$S.H.P._s$ = Shaft Horsepowers for these speeds

14,000 13,700 13,400 13,100 12,800 12,500 12,200 11,900 11,600.

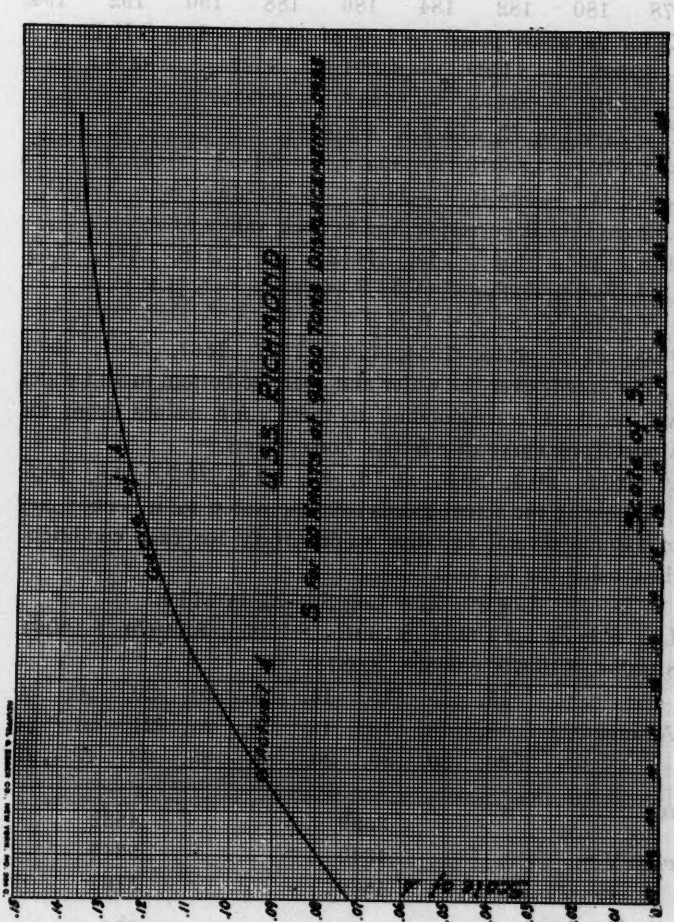


FIG. 1.

R_d = Revolutions with these powers for these speeds over bottom

178 180 182 184 186 188 190 192 194.

Z_g for the above powers = Log of 93,328 − Log S.H.P.$_d$ =

—.82388, —.83329, —.84291, —.85274, —.86280, —.87310, —.88365, —.89446, —.90555.

$Z_p = Z_g + \text{Log } K$, where $K = 1.03$ =

—.83672, —.84613, —.85572, —.86558, —.87564, —.88594, —.89649, —.9073, —.91839.

e.h.p. ÷ E.H.P. corresponding to these values of Z_p =

.159, .155, .152, .149, .1442, .141, .138, .135, .133.

e.h.p. corresponding = {E.H.P. × (*e.h.p.* ÷ E.H.P.)} =

53384 × (*e.h.p.* ÷ E.H.P.) =

8488, 8275, 8114, 7954, 7700, 7527, 7367, 7207, 7100.

The speeds over the water and over the bottom in still water will be those corresponding to these *e.h.p.* values from the Model Tank curve of effective horsepowers =

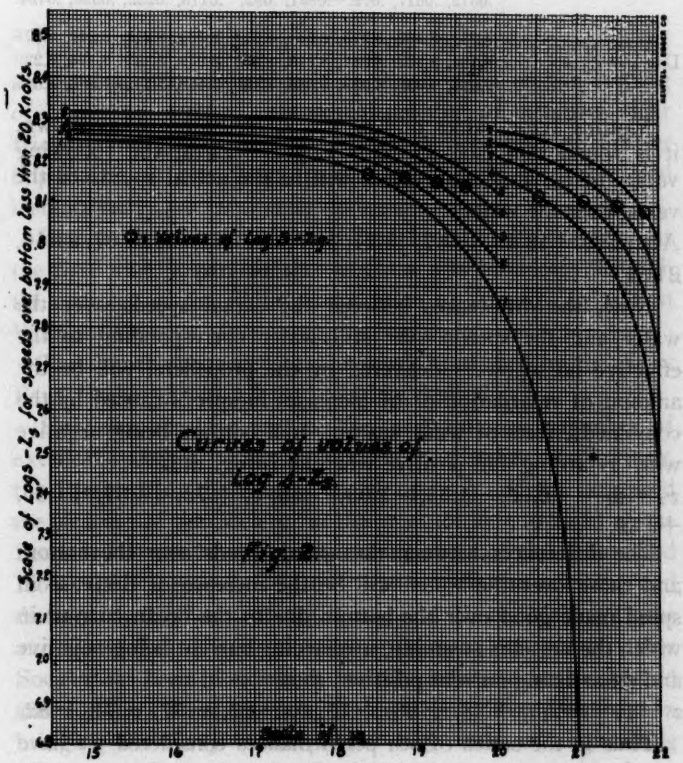
v_1 = 20.5, 20.4, 20.3, 20.18, 20, 19.8, 19.7, 19.6, 19.5.

To obtain the actual speeds over the water, v_2, it is necessary to assume several tentative values of v_2 for each condition; then, using the formula

$$\text{Log } s - Z_s = \text{Log } S - Z_g, \text{ in which}$$

Log S − Z_g = 8.16956, 8.16015, 8.15053, 8.14070, 8.13064, 8.12034, 8.10979, 8.09898, 8.08789.

Assume v_2 =	15,	15,	15,	15,	15,	20,	20,	20,	20
	18,	18,	18,	18,	18,	21,	21,	21,	21
	20,	20,	20,	20,	20,	22,	22,	22,	22
$v_2 \div V$ =			.3599				.4832		
			.4349				.5315		
			.4832				.5797		
Z_s =			1.21				.834		
			.97				.705		
			.834				.603		


Scale of Logs - Z_s for speeds over bottom less than 20 Knots.
Curves of values of
Log $\frac{d}{L}$ - Z_s
Fig. 2.

$$1 - s = \frac{v_2 \times 101.33}{P \times R_d} = \begin{cases} .7116, .7037, .696, .6884, .681, .8983, .8889, .8796, .8706. \\ .8539, .8444, .8352, .8261, .8172, .9432, .9333, .9236, .9141. \\ .9488, .9383, .9280, .9179, .9080, .9882, .9778, .9676, .9576. \end{cases}$$

$$s = \begin{cases} .2884, .2963, .304, .3116, .319, .1017, .1111, .1204, .1294. \\ .1461, .1556, .1648, .1739, .1828, .0568, .0667, .0764, .0859. \\ .0512, .0617, .072, .0821, .092, .0118, .0222, .0324, .0424. \end{cases}$$

$$\text{Log } s - Z_s = \begin{cases} 8.25, 8.262, 8.273, 8.284, 8.314, 8.163, 8.212, 8.247, 8.278 \\ 8.195, 8.222, 8.247, 8.270, 8.292, 8.049, 8.119, 8.178, 8.229 \\ 7.875, 7.956, 8.023, 8.080, 8.130, 7.469, 7.743, 7.908, 8.024 \end{cases}$$

Plotting these values of Log $s - Z_s$ on Figure 2, as shown, it is found that Log $s - Z_s$ = Log $S - Z_s$ at the following values of v_2, and these values will be the actual speeds of the vessel over the water:

Actual v_2 = 18.45, 18.87, 19.27, 19.6, 20.0, 20.52, 21.07, 21.46, 21.82.

Now, the differences between the actual speeds over the water and the speeds over still water corresponding to the effective horsepowers delivered by the propellers, will be the amount of retardation or of increases in speeds caused by the combined effects of wind, sea and foul bottom, being negative when retarding and positive when assisting, thus

$v_2 - v_1$ = −2.05, −1.53, −1.03, −.58, 0, +.72, +1.37, +1.86, +2.32.

The differences between the actual speeds over the bottom and those over the water will be the increase or decrease in speed made good over the bottom due to the ocean current in which the vessel is steaming, a retarding current being negative and an assisting current positive; thus

$v - v_2$ = +.55, +.38, +.23, +.15, 0, −.27, −.57, −.71, −.82.

Thus in the series of sea performances considered we have passed from a condition of unfavorable head wind and sea and foul bottom, approximating a loss of 2.05 knots in speed, but with a favoring current of .55 knots, through a condition of still water with no unfavoring conditions, to a condition where we have a favoring wind and sea to the extent of 2.32 knots increase in speed, the speed over the bottom, however, being decreased by an unfavorable current of .82 knots.

THE ANNUAL BANQUET.

In accordance with the custom of the Society for many years, the Annual Banquet was held at Washington on the evening of March 14, 1925. This annual meeting of members, their friends, and guests of the Society, is becoming of greater importance as the years pass. It is both enjoyable and instructive.

It took place at the New Willard Hotel and this year, for the first time, a part of the program was broadcast through the courtesy of the Radio Corporation of America by station WRC.

The dinner was excellent, the music furnished by the Navy Band Orchestra was all that could be desired.

However, the best part of the program was a number of excellent speeches. Rear Admiral C. F. Hughes, U. S. Navy, the President of the Society, in his opening address expressed the pleasure of the Society "at the presence here to-night of the Secretary of the Navy, prominent members of the Senate and House of Representatives, men eminent in the sciences, and distinguished officers of the Army and Navy, Marine Corps and Coast Guard, and to welcome them as our guests. Our Society has been in existence for 37 years, and has numbered and does now number among its members, those prominent in bringing the Navy to its present high state of engineering efficiency. In engineering is included every branch of the science—optical, aerodynamical, electrical, hydraulic, and every other that may be found in the dictionary or encyclopedia. Much has been done by this Society in the line of education in the service at large. At the time of its foundation there was a current belief that some captains considered that vacuum

was carried in the store room, and that the speed of main engines could be increased 10 to 15 revolutions without increasing the consumption of fuel. But those days have passed, and the stories, if true, only remain in the memory of the founders of this Society and their contemporaries.

"The future of Naval engineering presents harder tasks than in the past. By an agreement the weight of certain ships and the sizes of their guns have been limited, and it is only reasonable to suppose that competition under limitation will be even more keen than before, and thus the problem of the naval engineers becomes more exacting. We must find means of doing more on the same weight than any other nation, and this is the question that confronts you, not to-morrow but to-day. This may be done by the development of new metals, improvement in structural and mechanical designs, accompanied by some sacrifices in the luxuries, conveniences and even comforts that we have previously enjoyed, but it must be done."

In closing he turned over the program to "an officer of wide and varied experience, energetic, progressive, and with a justly high reputation for efficiency"—Captain W. T. Cluverius, U. S. Navy.

The Toastmaster lived up to his reputation as a Naval Officer, adding to his laurels.

The first introduction was of the Honorable Curtis D. Wilbur, Secretary of the Navy, who in a short informal address reviewed the progress of the Navy in a material way. The Secretary, who it is well known is a graduate of the Naval Academy, class of 1888, the same class as the President of the Society, and the same year as this Society was founded, closed his remarks with this reference:

"I think I may add a personal word of gratification at the experience which has come to me after years of civil life, passed along entirely different lines, dealing more especially with the fundamentals of human conduct and the problems of human nature and of government, and to come back and find these

men who have been dealing with the problems of the forces of nature, of steel, of steam, of electricity, of communication, of warfare, and who have successfully conducted the Navy of the United States in that period through two great wars, in which America has emerged from her isolation into world prominence, and has become one of the dominant world powers."

Rear Admiral Hilary P. Jones, U. S. Navy, favored those present with a scholarly address on a subject of lively interest. It will be found complete in this issue of the JOURNAL.

Among our invited guests was Doctor M. I. Pupin of Columbia University, President of the American Association for the Advancement of Science, who had consented to address the Society on the subject "Science and Engineering." The thoughts of this distinguished scientist and engineer as expressed at the dinner are also published in this issue.

The Society was fortunate in being able to hear from Leigh C. Palmer, who needs no introduction, as regards the Emergency Fleet Corporation. Admiral Palmer has taken his Naval training, his knowledge of Naval accomplishments, and the Navy spirit of service, to his present job. He has accomplished a great deal in reducing expense and at the same time increasing efficiency.

There were many distinguished guests and members present, and time permitted of calling upon only a few for short informal remarks, and the toastmaster did well in his selections of Senator Tasker L. Oddie, of Nevada; Admiral E. W. Eberle, Chief of Naval Operations; Rear Admiral J. K. Robison, Engineer-in-Chief of the Navy, and Rear Admiral F. G. Billard, Commandant of the Coast Guard.

Senator Oddie said so many nice things in his few remarks that it would not be right to deprive those who were not present of his pleasing words. It is with great pleasure that we quote him as follows:

"*Mr. Toastmaster and friends*: I have prepared no address to-night, and after listening to the very able ones delivered here, I feel that if I were technically educated in these matters, it would not be worth while for me to try to tell you anything more about these extremely interesting questions which have been discussed. We hear a great deal to-day about the conflict between the aeroplane and the battleship. I feel that it is because of a lack of understanding. The extremely able address of Admiral Jones that we have just listened to shows that the Navy itself is the strongest supporter of the aeroplane, but not at the expense of the battleship. My friends, these shells that are being constantly hurled at the battleship to-day, charged with lack of information and with misinformation, are doing a great harm in breaking down the morale and encouraging Americans to sneer at that great engine in preserving the peace of the world. Lack of understanding and lack of knowledge is an enemy that will penetrate, or it has forces that will penetrate, any armor that can be invented by man, and the battleship cannot withstand, our civilization cannot withstand, such attacks. I personally saw the sinking of the *Ostfriesland*, and while too much credit cannot be given the men in the aeroplanes who did that wonderful piece of work, it proved to me as a layman that it was not a fair test. You men know more about this than I do.

"Now I want to say something about the personnel of the Navy. I have been particularly privileged in having had opportunities of being with the Navy men a great deal. I do not have to apologize for saying something strong, but I think they are the best men there are anywhere. I know as a legislator for I have had something to do with selecting the young men for the Naval Academy, and I know and my colleagues know that great care is exercised, and that the very flower of American manhood is picked for the Navy. I would like to pay a tribute to the accomplishments of the Navy besides the war accomplishments—the building of great naval ships and

of guns and of ammunition. I personally came in contact with something of what the Navy has done in San Domingo. There the Naval officers showed their ability not only as jurists, as they had to be, but as road builders, as educators, and as directors of governmental affairs generally. You are all familiar with the wonderful roads that our naval officers built in San Domingo. They cannot be excelled in any country and they were built at comparatively low cost. You probably know that when the naval officers took hold of the school system of San Domingo they raised the attendance from something over 20,000 to something over 100,000, and they raised the percentage of attendance from something like 22 to 80 and 90 per cent. So I feel that the men of our Navy are the best in the world, and my impression ought to be the impression of all of the American people. They show judgment and ability in many lines, and I wish the great body of our people could know more about them, and about what they do besides the regular routine Navy work. And I want to say, my friends, as a legislator, that there has been a better understanding between the Navy and Congress, both Houses of Congress, this year than there has been for many years past. One result is the passage of the Omnibus Bill. Another is the passage of the Naval Reserve Bill which I had considerable to do with, and I want to suggest this: that as that Naval Reserve Bill is a product of the Navy, it was drawn by some of the very best officers in the Navy, and it was passed with very few changes, that the Navy should take especial interest in the Naval Reserve. Remember that the Naval Reserve should be composed and will be composed of some of the very best men in this country. They envy you graduates of the Naval Academy. Give them the right hand of fellowship, encourage them, they look up to you as big brothers.

"My friends, I have talked longer than I intended to, and I thank you very much for this opportunity of being with you to-night."

There was a time, and within easy memory, when a Naval Officer could not be counted on to make a speech. This age has been disappearing, and it was with genuine enjoyment that the address of Admiral Eberle was listened to.

"Mr. Toastmaster and gentlemen: After the very illuminating addresses we have heard to-night I think that your Toastmaster has a great deal of faith in calling upon me for three or four minutes. It reminds me of an old negro preacher who was preaching on faith. He had the Bible before him and he said: 'My friends, if you only have faith you can do anything. Now there was Daniel in the lion's den. He had faith and them lions never touched him.' An old man down in the audience said: 'Parson, do you think that them was real lions? Wasn't them circus lions that never touch anybody?' The old man slammed his hand down on the book and said: 'The Bible expressly states that this was B. C., which according to my interpretation means before circuses.'

"Now I wish to assure this Society that the American Navy has perfect faith in the American Society of Naval Engineers, like the old parson had in Daniel in the lions' den.

"This is an age of engineering knowledge and progressiveness. With thousands of automobiles in cities and in towns and throughout the country, and with motor trucks and farming implements, and with motor boats and auxiliary motor yachts and schooners, and with military and commercial aircraft in rapidly increasing numbers, man in his daily work and in his recreation comes in almost constant contact with high speed machinery, and he is compelled to acquire at least a working knowledge if not a scientific knowledge, of the operation and care of such high speed machinery.

"All graduates of the Naval Academy now on the active list of the Navy had the engineering course at the Naval Academy and have had engineering duty and experience on board ship.

"It is absolutely essential to proper and efficient command to coordinate engineering knowledge and activities on board ship

into one great operating force;—that is, activities on the bridge, in the conning tower, in the engine room, in the turrets, in the dynamo room, in the plotting room, in communications (radio, sound and visual), and with the aircraft, must all be coordinated into one great fighting team or striking force if success is to result. All such activities are based on sound knowledge of seamanship, tactics, strategy, gunnery, aviation, and the intelligent use of electrical and mechanical power. Knowledge of economy of operations of such installations and their maximum possibilities when called upon must be known to those in command.

"Gentlemen, all officers from the Naval Academy speak the same language of the sea, speak in the same sea terms, understand the same engineer's vocabulary. When I was Superintendent of the Naval Academy a few years ago we were having a graduates' dinner, and one of the old graduates came to me and said: 'The Naval Academy is entirely changed. All the old buildings are gone. I see none of the old monuments in the same places; I see none of the old professors and instructors. All is changed.' I said: 'The Naval Academy doesn't mean buildings, the Naval Academy doesn't mean men, it doesn't mean instructors or professors, or a corps of midshipmen. The Naval Academy means that idealism, that high character, that love of country, that comradeship, that loyalty to the flag, that intangible something which we call the spirit of the Navy.' And, gentlemen, that is the spirit that actuates the Navy to-day, because all its officers are trained to speak the same language and to work together,—and no matter what ships, what equipment you gentlemen furnish us with, the fact remains that in the final analysis it is the human element,—the human element that is charged with the responsibility and the operation of the intricate machinery, that moulds ships into one great fighting force, actuated by the Spirit of the Navy. The Navy has never failed the people of this country, it never will. I ask you, gentlemen, to have faith in the Navy."

Time was passing and Admiral Robison in his remarks commented very briefly upon the "spirit of unity" in the Navy which exists now in contrast to that which existed prior to the time that all line officers were not engineers. In referring to this time and to the duty of the engineer, he said:

"Admiral Eberle, the Chief of Operations, boasts of the fact that we all—the line officers, are engineers. Times surely have changed. When we have arrived at that condition let us be thankful. Plans now are built not upon the dreams nor the vain imaginations of a zealot, but they are founded upon facts. They are developed by sound engineering methods into practicable means for accomplishing the security of this our country. That is a definite engineering service, first to the Navy, and of course to the nation. All of us join with full heart in praying that this nation's sword shall ever remain in its scabbard; but to us engineers is given the duty of making sure that if necessity demands that that sword be drawn, the blade shall be sharp, the blade shall not be rusty, and that the blade shall be wielded by competent hands."

The Commandant of the Coast Guard called attention to several matters that deserve consideration which could not be better stated than to quote his remarks.

"*Mr. Toastmaster and gentlemen*: One of the routine features of my duties as Commandant of the Coast Guard is to sign innumerable requests to the various Bureaus of the Navy Department asking them to give something to, or to do something for, the Coast Guard. These requests are almost always granted cheerfully and readily. If one is refused, the declination is couched in the most courteous terms and the alibi is perfectly convincing.

"Permit me on this public occasion, as I should like to do on any appropriate occasion, to express my profound appreciation of the great help that the Navy Department and its various Bureaus are constantly according the Coast Guard. It is an example of the finest kind of co-operation between different

branches of the federal service; and, when the opportunity comes, as it does occasionally, for the Coast Guard to do some little thing for the Navy, you may be sure that that opportunity is seized with enthusiasm. Let me in just a minute or two suggest a thought that I should like some of you to take with you from this most delightful and instructive banquet, and that is the very close relationship and connection between the Navy and the Coast Guard. The main purpose of the Navy, of course, is to defend the nation and its commerce in time of war. And, in time of war what is the Navy? It is the equipment and personnel of the regular peace time Navy, enlarged as the exigencies of the case require; it is the officers and men of the Marine Corps, of course; and it is the Coast Guard, because the Statutes of the United States provide that the Coast Guard shall operate as a part of the Navy, subject to the orders of the Secretary of the Navy, in time of war or whenever the President shall so direct. And so any increase or betterment in the equipment or personnel of the Coast Guard, or any increase in the efficiency or training of its personnel is a direct contribution to the resources of the Navy in its main mission of service in time of war. Now the officers and men of the Coast Guard who pass into the Navy in time of war, and with whom you gentlemen will serve, are not at present engaged in civilian pursuits ashore with only an academic interest in naval matters. They are almost constantly at sea on small ships. They are operating destroyers of the Navy; they are drilling of necessity the men with guns in target practise, in radio, in signals, in engineering, and they are ready at a moment's notice to join you. Just at present, in addition to the pressure of regular duties, they are engaged in the pursuit of rum runners, a form of duty, which I may say in passing, that should be of considerable value in connection with war training.

The Coast Guard is not under any illusions with respect to this particular duty that has been laid at its feet. It knows

the size of the job, its difficulties, its discouragements, and its lack of popular appeal. But the attitude of the Coast Guard toward this job is best expressed by the reply that the good sailorman makes to an order: "Aye, aye, sir." It is precisely the same spirit that has always animated and will always animate it when it is given a job to do whether it likes it or not.

Is the Navy interested in some 300 commissioned officers, most of whom are graduates of a three years' course of training as cadets; in nearly 9000 trained, seamanlike, warrant officers and enlisted men? Of course it is. But may I respectfully suggest this wish. I should like all the ranking officers of the Navy to be indoctrinated with this general principle; that whenever any problem or any matter affecting the Coast Guard comes to their attention that they should instantly recall the provision of the Statutes of the United States, that in time of war, or when the President shall so direct, the Coast Guard becomes a part of the Navy, and that they should take the attitude that anything given to the Coast Guard, anything done for the Coast Guard, is not given to or done for outside parties, but is all in the family, and constitutes an increment of the resources of the Navy itself. Within the Coast Guard we look upon the Navy as a big brother. Now in the humdrum routine of life brothers may find themselves engaged in somewhat different activties. At times they may not be concerned with each other's interests and problems to the exclusion of their own; but the bond is there, and in time of stress or difficulties or conflict they will be found arm in arm to meet the common issue. May I say this in all sincerity and earnestness, that there is no body of men in the world outside of the commissioned officers of the Navy and Marine Corps, who are more deeply interested in or more concerned with the welfare, the development, the prestige, the success of the United States Navy than are the commissioned officers of the United States Coast Guard."

As the Toastmaster aptly stated in bringing the program to a close, it was not because the "reservoir is exhausted."

Admiral Hughes was compelled to leave the dinner early to catch a train for the Pacific Coast, and those present were dismissed with a few remarks by a Past President of the Society, Rear Admiral R. S. Griffin, U. S. Navy, who expressed the thanks of the Society to the speakers, guests, and the committee in charge for its success.

NOTES.

ADMIRAL GEORGE WALLACE MELVILLE: A GREAT LEADER OF THE ENGINEERING PROFESSION.*

By Walter M. McFarland.†

The desire to perpetuate the memory of great men by some form of monument made of imperishable material must go very far back in the history of the race. We know that it certainly appears in prehistoric times. In the majority of cases these monuments have taken the form of a statue of the hero, and it is always a matter of interest, when one knows his history, to study the face and see whether the characteristics shown in actual life have been grasped and delineated by the sculptor.

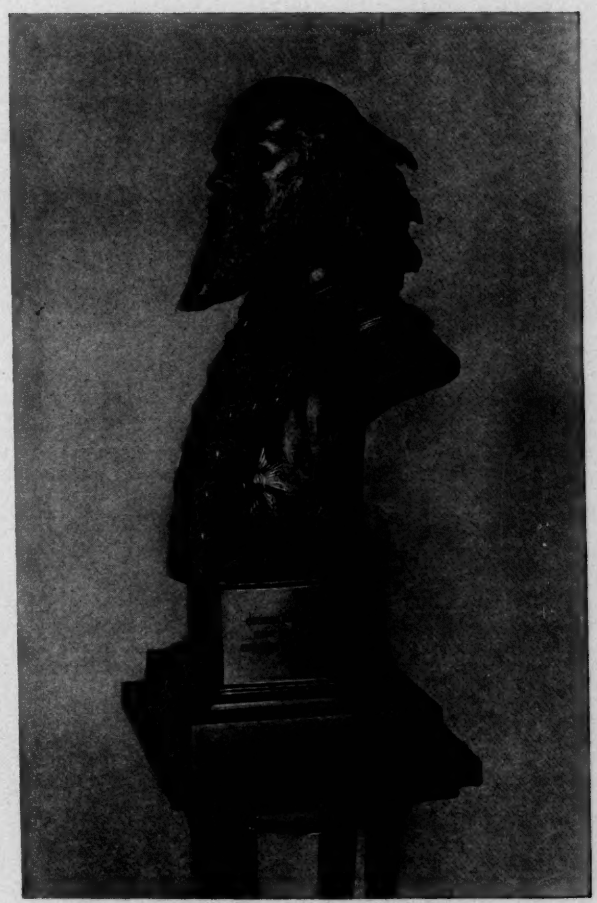
When examined in this way the statue of the late Admiral Melville, which is before us for presentation to the Society, clearly shows the leading elements of his character which went to make him one of the great leaders of our profession. These elements I should list as great will power, tenacity of purpose, absolute fearlessness, and leadership. Indeed, many people who knew him in life and others who have looked at his pictures have said that he was really one of the old Vikings who had appeared a thousand years after all the rest had gone.

ADMIRAL MELVILLE'S FEARLESSNESS, TENACITY, AND RESOURCEFULNESS.

As an example of his fearlessness and tenacity we have the case of the capture of the Confederate privateer *Florida* in 1864 in the harbor of Bahia by the United States vessel *Wachusett* where Melville was one of the junior engineers. It was, of course, a breach of international law to attack an enemy vessel in a neutral port, but the captain of the *Wachusett*, remembering the vicious work of the *Florida* in sinking helpless merchantmen, probably felt justified in risking his commission (which, as a matter of fact, he lost) by capturing her. Melville volunteered to go aboard the *Florida* to secure information, and took the risk of being arrested and executed as a spy. His visit was very brief but he did learn much of value. A council of war was held on the *Wachusett* and it was decided to attack the *Florida* by ramming. Fear was expressed by some of the officers that the shock of ramming would dislodge the boilers from their fastenings, thus breaking steam joints and scalding everybody below. Melville volunteered to stay below alone and operate the engines so that, if such an accident occurred, he would be the only one sacrificed. We know now, from the experience of many collisions, that there was no danger of such an accident, but it was not known then and he was sincere in what he believed to be a tremendous risk.

* Address delivered on the occasion of the presentation of the Melville bust to "The American Society of Mechanical Engineers" on December 3, 1924.

† Mgr. Marine Dept., Babcock & Wilcox Co., New York, N. Y. Past Vice-President, A. S. M. E.



THE MELVILLE BUST, PRESENTED TO THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS DECEMBER 3, 1924.

After the close of the Civil War he was almost constantly on sea duty and established a reputation for efficiency and resourcefulness which made all the older engineer officers eager to have him on their staff. In 1873 a relief expedition was undertaken to rescue a portion of the crew of the *Polaris* expedition (of which Captain Hall was the commander) and the yacht *Tigress* was chartered for this purpose. Melville volunteered as her engineer officer, and although the machinery was old and worn, his indomitable spirit and technical skill made it work, so that the *Tigress* succeeded in getting as far north as the winter quarters of Dr. Kane in a little over thirty days. The *Polaris'* survivors had gone forward and had been rescued by a whaler. Unaware of the safety of the party, and during the fierce autumnal gales of the Arctic, the *Tigress* kept up the search to the great satisfaction of the commander, Captain Greer, U. S. N., who stated officially that, despite the miserable condition of the boilers and the cheap machinery, Melville's great fertility of resource combined with thorough practical knowledge enabled them to carry on. It was on this trip that Melville and DeLong became associated, which led to their again being shipmates in the ill-fated cruise of the *Jeanette*, where DeLong perished and Melville established a record for heroism which has never been surpassed.

THE VOYAGE OF THE "JEANETTE."

The story of the voyage of the *Jeanette*, and of the retreat over the ice after the vessel was crushed and sunk, has been told in Melville's own book entitled, "In the Lena Delta" and in the "Ice Journals" of Captain DeLong. It is a story which, as a record of courage and persistence under most trying circumstances, cannot be surpassed and it has all the fascination of romance. Almost innumerable opportunities were presented for the display of his resourcefulness and technical skill in various small ways which contributed to the safety and maintenance of the vessel; and time after time Melville was called upon for special efforts entirely apart from the machinery where his wonderful qualities of leadership, persistence and courage stood out preëminently. When the group known as the DeLong Islands was discovered, Melville was given command of a party to make a landing and survey on Henrietta Island. DeLong comments upon the tremendous difficulty of this work as follows: "Near the island the ice was all alive and Melville left his boat and supplies, and carrying only a day's provisions and his instruments, at the risk of his life, went through the terrible mass, actually dragging the dogs, which from fear refused to follow their human leaders. If this persistence in landing upon this island, in spite of the superhuman difficulties he encountered is not reckoned a brave and meritorious action, it will not be from any failure on my part to make it known."

After the sinking of the *Jeanette* it became necessary to travel southward over the ice, dragging the boats on sledges, until they could come to the open sea. The crew was a small one and it was necessary for the entire party to haul the larger boats one at a time, with the result that for each mile made good there was an actual travel of about thirteen miles. The entire journey in this way amounted to some 1300 miles over this terribly broken ice. We are apt to think of traveling on the ice from our own experience with the smooth surface of ponds and rivers, but it has been graphically described as attempting to travel over the roofs of a lot of three-story houses all bunched together. Finally water was reached, they took to the boats, and the whaleboat under Melville's command was fortunate enough to enter an arm of the Lena River, where they fell in with natives and so escaped starvation. DeLong's party entered another mouth, did not fall in with natives, and all perished except the two strongest men, who had been sent forward at an earlier stage. When Melville got in touch with these survivors and learned of the possibility that the remainder of the party might

be rescued he undertook a search for them. The account of this journey in the Arctic winter is a record of heroism and tenacity of purpose which has rarely been equaled. He was alone with two natives, as guides and dog drivers, with whom his communication had to be mostly by signs. The weather was so fierce that even these hardy natives were cowed and wanted to turn back. His feet were frozen and he was almost helpless, but his great will power dominated the natives and forced them to proceed until it became evident that further search at that time was useless because the party must long since have perished. The next spring he searched for them again, found the bodies, and gave them decent burial.

On his return to the states he was acclaimed a hero, but recognition by Congress was delayed a long time, and when it did come, almost ten years later, it amounted to an advance of only about ten numbers, although it was a grade in rank.

By this time Melville was one of the foremost figures in the Engineer Corps of the Navy, and the duty to which he was assigned was commensurate with his recognized professional ability and skill as an executive. When the building up of what was called the "New Navy" forty years ago began, Melville was assigned to duty as Senior Inspector at Cramp's Shipyard where a number of the vessels were under construction. At that time we were obsessed with the idea, which still lingers occasionally, that everything is better done in Europe than here at home, with the result that we bought the plans for some of our earlier vessels in England. Melville believed that he could get out designs which would be equal or superior to these and asked permission to do so. This was granted and he associated with him Chief Engineer Kafer, a contemporary, and Messrs. Mattice and Cathcart, all of them members of this Society, as well as other younger men, and together they produced the designs for the machinery which was installed in the cruiser *San Francisco*, which was one of the most successful of our early ships, as I can testify from personal service on board.

MELVILLE'S CAREER AS ENGINEER-IN-CHIEF OF THE NAVY.

About this time a change was made in the office of Engineer-in-Chief. Secretary Whitney, knowing of Melville's wonderful record, recommended his appointment by the President, so that he became Engineer-in-Chief of the Navy in the summer of 1887. At this particular time the fortunes of the Engineer Corps of the Navy were at about the lowest ebb in its entire career. There were many good officers in the Corps among the older men, and for nearly fifteen years the Naval Academy had been turning out engineer graduates of whom many have made their mark in the profession. Two of them have already been Presidents of this Society, Messrs. Hollis and Cooley, and a third is about to become President in the person of Dr. Durand. What had been lacking was a virile, fearless leader. With the advent of Melville the leader had come.

His first official report as Engineer-in-Chief, written a few months after he took office, was like a cyclone compared to a zephyr in contrast with the mild effusions of his predecessors since Isherwood. It aroused a storm of criticism which went so far that certain line officers of the Navy endeavored to arouse in President Cleveland the belief that Melville was a "firebrand" and "disturber of the peace." Fortunately Cleveland was built on very much the same lines as Melville, not only as to physique, but as to character. Naturally he wanted to see the report, and when he had read it, so far from finding fault or removing him, as these officers had hoped, he said that this was the kind of man he had been looking for and he only wished the Navy had more of them.

Melville was reappointed three times, so that his service as Engineer-in-Chief lasted for sixteen years, the longest career of any bureau chief in the

history of the Navy Department. The whole record was one of progress, both professionally in design and construction of machinery, and in the morale and standing of the Engineer Corps. He was thoroughly progressive but prudent and careful, so that there were no breakdowns and each new ship was an additional success. Outstanding features of his work are the engines of the first battleships, of the armored cruisers *New York* and *Brooklyn*, the three-screw flyers *Columbia* and *Minneapolis*, which were the fastest large vessels in the world of their day, and the introduction of water-tube boilers.

As an illustration of the improvement in morale it may be mentioned that at the beginning of his term there was such a tremendous demand for lightness of machinery that weights were skinned down to a minimum and boiler tubes were quite thin. Within a year after the commissioning of some of the vessels there began to be trouble from corroded tubes. This was entirely unreasonable with proper attention, but an investigation showed that the cause was perfectly simple. When anything occurred to change the trim it was very much easier to run water up and down in the boilers to trim ship than to shift the boats or take other proper but less easy methods. If a scheme had been sought to ruin the boilers in the quickest time nothing simpler could have been devised than running salt water in and out of them. As soon as Melville knew this, he went to the Secretary, explained the situation, and stopped it in a very simple way. He prepared an order, which was signed by the Secretary, forbidding the use of the boilers for trimming ship and also forbidding the introduction of salt water in them except in case of emergency. If such emergency were deemed to have arisen the fact was to be entered in the engine-room log in red ink and the captain was to make a special report justifying his action in endangering the life of the boilers. This absolutely stopped the practice.

A GREAT LEADER OF THE ENGINEERING PROFESSION.

The success of Melville's designs gave him international fame and he was looked upon everywhere as one of the great leaders of the profession. He had none of the spirit of secrecy which sometimes obsesses public officials and believed that, as the people of the country were paying the bills for the Navy, it was only fair that they should get such benefit from the work done as was practicable. Accordingly, in his annual reports he always included drawings showing the prominent features of the new designs, and these were undoubtedly of great value in stimulating engine builders everywhere to excellence of design and workmanship.

An event of the greatest importance in the history of the Navy was the amalgamation in 1899 of the Engineer Corps with the Line, thereby establishing beyond all question the proper status of the engineer on board ship as a fighting man. I believe that this was due in very large measure to Melville's personality, his established leadership, and the great record which he had made when the amalgamation was proposed. Another active factor was Dr. Hollis, who had been an engineer officer of the Navy for many years before going to Harvard as professor of engineering, and who had urged this procedure upon Assistant Secretary Roosevelt, afterward President. A board consisting of line and engineer officers under the chairmanship of Mr. Roosevelt was formed where Melville was the head of the engineers and I was their junior representative. It was perfectly evident from the start that Melville's personality and wonderful record were the deciding factors where differences of opinion arose. As a result of this amalgamation the fighting officer of the Navy today is primarily an engineer and the Naval Academy is a great school of engineering. To his basic training as an engineer is added appropriate work in ordnance, navigation, and seamanship to make the competent naval officer.

There was one feature of his character which perhaps does not show in his statue but which was a vital element in leadership, namely, his big heart and keen sympathy with his subordinates. No one could have asked to work for a chief who was more stimulating and at the same time considerate. All of us youngsters who had the privilege of serving under him admired him as a hero and a great engineer and we loved him as a father. He was always ready to give credit to his assistants in the most generous way. He was great enough to realize that he could give credit to his assistants without losing any himself. We were always ready to answer any call and thought nothing of working on nights and Sundays when it became necessary, counting it a pleasure to do it for the "Big Chief."

ACHIEVEMENTS FOLLOWING RETIREMENT FROM ACTIVE DUTY.

He retired from active duty in the Navy in 1903, but a man of his active disposition could not be idle. He opened an office as consulting engineer and kept busy until his death. The outstanding feature of this period is his origination of the use of gearing to enable the steam turbine to be adapted economically to marine purposes. Now that it has become an established practice, it seems perhaps that it ought to have been apparent to everybody in the beginning; but the fact is that there was anything but agreement at the start that this was the best method. He aroused the interest of George Westinghouse in this idea, who furnished the money and the plant for making the early tests. During this period also he was very active in the scientific societies in Philadelphia, where he made his home. He was one of the best-known citizens, and with his long white hair and beard and handsome features was a most striking figure.

Naturally he kept up his interest in Arctic exploration and was one of the recognized authorities on this subject throughout the world. I should have said before that not long after his return from the *Jeanette* he was Chief Engineer of the *Thetis* of the Greeley Relief Expedition. On his return from that trip he was eager to go in command of an expedition to the North Pole. Unfortunately the money could not be raised to defray the expenses, so that his hopes were frustrated. It is most interesting, however, to know that he outlined in his book a plan which in essence, although modified by his greater experience, was followed by Peary in his successful discovery of the Pole. It is very pleasing to me, and I am sure was to all his friends, to notice how prompt Melville was in detecting the fraud on the part of the notorious Dr. Cook when he claimed to have discovered the Pole, although he had only gone a degree or two north of the eightieth parallel. Melville had perfectly good reasons which were convincing to me. At that time I was living in Pittsburgh and a great many of my friends believed in Cook and jeered at me for being a scoffer. They said, "You only say so because Melville says so. If he said the moon was made of green cheese you would say so, too!" This sneer was in reality a wonderful compliment to the affectionate relation which had long existed between the great Admiral and myself, which was almost like that of father and son. It is often said that no man can be a hero among his intimates, but this was not true of Melville. Those of us who were intimately associated with him and who knew him best, only grew to admire and love him more and more.

Mr. President, I realize that this very brief and wholly inadequate sketch of our great friend does him far less than justice. I can only ask you and my fellow-members to take the will for the deed, and to believe that if I were an orator I could give you an account of our departed leader which would fully satisfy your own sense of what is right and fitting.

An opportunity occurred to procure this bust* and it was believed that

* The work of Samuel Murray, a sculptor of Philadelphia, Pa.

it would be a real pleasure to the many friends connected with the profession who had known him personally to join in its purchase and presentation to our Society. A committee was formed and an invitation to participate sent out with the definite statement that it was only sent to personal friends and those who would feel it a privilege to take part. Practically every one who was invited joined in the subscription, so that it represents a testimonial from about one hundred and thirty of the Admiral's friends. To me has been accorded the honor of acting as their spokesman in presenting this bust to The American Society of Mechanical Engineers, which had honored him by the Presidency of the Society and also with Honorary Membership. A more fitting place for this imperishable memorial could not be found than the rooms of our Society where it will share the honors with the statues and pictures of other great engineers. Our hope is that, as time goes on, younger men to whom his name is only a memory will be led, by looking at this superb reproduction in bronze, showing the wonderful characteristics which I have already mentioned, to study his life and from it gain an inspiration to add to the glories of the profession and to build up for themselves a great reputation.—"Mechanical Engineering," Feb., 1925.

BELGIAN ENGINEER DEVELOPS INTERNAL-COMBUSTION BOILER.

Oil Flame Burns Under Water—Air and Oil Supplied at Boiler Pressure—Inventor Claims Extraordinary Efficiencies—Combustion Products Pass to Engine with Steam.

The idea of burning fuel directly in contact with the water of a boiler is by no means new, but in spite of the fact that previous attempts have not resulted in commercial success, the idea will not stay down. The latest experiments along this line have been made by Oscar Brunler, a Belgian engineer, who presented a paper describing his apparatus before a joint meeting of the Institution of Chemical Engineers and the Chemical Engineering Group of the Society of Chemical Industry, at the Institution of Mechanical Engineers, in London, on February 11.

According to Mr. Brunler the first internal-combustion boiler that would operate continuously was made fourteen years ago. This, he said, was not a commercial proposition and two more years passed before the boiler had reached a stage where it could be guaranteed to work for months without breaking down. At the outbreak of the war orders had been placed for about twenty of these boilers in various industries, but destruction of the factory in Belgium when the war broke out prevented the carrying out of these orders. The work had been going on under the leadership of the father of the present Brunler. On the death of the father, at about this time, the son carried on the work. He stated in his paper that it was in 1922 when he succeeded in building a boiler that worked continuously for months.

The following paragraphs are a digest of certain portions of Mr. Brunler's paper.

All designs of boilers are based on the principle of bringing the flame of the fuel in the closest possible contact with the water in the boiler. Why not burn a flame in immediate contact with a liquid? This is easily accomplished, as is shown by the working of the internal-combustion boiler, the principle of which is to maintain a flame burning in the liquid in order to evaporate the latter. During the years of experimenting, liquid hydrocarbons of specific gravities ranging from 0.8 to 1.2 have been used. More than sixty different kinds of oil from many countries have been tried, and

all these could be burned without difficulty. Fig. 1 shows the complete apparatus, consisting of a central steam and water storage drum connected to several steam generators.

The fuel oil and the air necessary for combustion are supplied to the burner under a pressure that barely exceeds that of the steam. Before starting, the connection valve is closed, and the water level in the generator must not be above the lower mouth of the burner. The cover of the ignition lamp is removed after heating the fireclay lining of the ignition lamp; the oil and air ignite on the fireclay lining. Then the cover is pulled down again, and the flame of the ignition lamp makes its way to the burner. After a few minutes the main burner is hot enough whereupon the main regulating valve is opened and the flame burns in the generator.

Now the connecting valve to the water reservoir is opened and the water in the generator rises up to the middle of the burner. The flame, which burns quietly in the water, can be observed through the peep-holes in the generator.

By means of the superheater the steam can be superheated to any required degree. The superheater consists of a small burner similar to the ignition lamp, and its flame burns in the steam reservoir. The size of the flame and

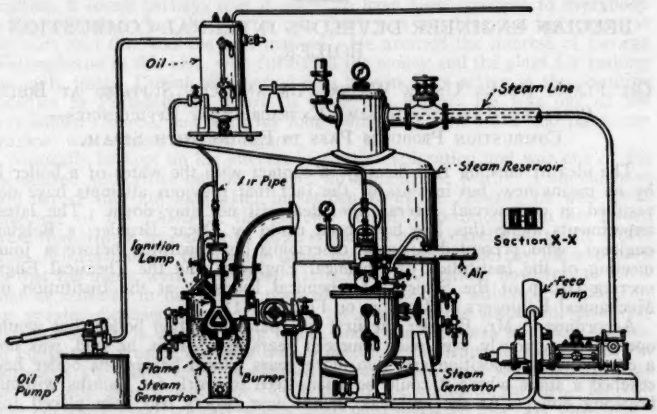


FIG. 1.—ELEVATION OF COMPLETE APPARATUS SHOWING ONE STEAM GENERATOR IN CROSS-SECTION.

consequently the quantity of steam is regulated by means of the regulating valve; at the same time the ratio of oil and air is kept constant. By turning one wheel, the size of the flame can be regulated, without changing the ratio of fuel and air. Therefore, it is not possible that the combustion can be altered through mistakes of the stoker.

The temperature in the center of the flame is approximately 3300 degrees F. This temperature diminishes to the periphery of the flame, so that between the center of the flame and the periphery a rapid fall of temperature takes place. Since a permanent stream of burning gas has to pass this fall of temperature, it is evident that the last traces of carbon-monoxide must be converted* into carbon dioxide.

* It should be noted that this and the later claim of efficiencies exceeding 100 per cent are merely reports of Mr. Brunler's statements and do not represent the opinion of the editor. Further comment will be found on the editorial pages.

[Here Mr. Brunler went on to compare the working of his complete plant with that of an oil or gas engine. Admitting that the Brunler outfit required a compressor to deliver the combustion air against boiler pressure, he pointed out that the oil engine likewise had to compress its air. The substance expanded in the engine with the Brunler outfit was a mixture of nitrogen, carbon dioxide and steam. The same substances were present during the expansion stroke of oil engines, though in different proportions. These comparisons were apparently drawn to give the impression that the Brunler plant was theoretically equivalent to an oil engine. In comparison with an ordinary steam plant, the impossibility of operating the Brunler plant condensing was admitted, but it was claimed that high efficiencies were obtainable in spite of this limitation.—Editor.]

In practice we have obtained, in certain cases, more than 100 per cent efficiency; consequently, there must be either a slip in the experiments or in the determination of the calorimetric value. All the experiments have been carried out so carefully that there must be a missing factor in our present formulas. There must be some kind of latent energy that is set free during combustion which we cannot utilize at the present time. So far there is no way to analyze this.

I am of the opinion that under certain conditions, which are still unknown to us, electric vibrations produced during the combustion are converted into useful energy, and thus a higher efficiency than 100 per cent is obtained. During the tests that have been carried out with the submerged flame, evaporations have been obtained that surpass the theoretical ones. Samples of the oils used during the tests were chemically analyzed and burned in the calorimeter and the exact calorimetric value of the oil was determined, but for weeks and weeks a higher calorimetric value and consequently a higher efficiency than 100 per cent was obtained in the generator.

I shall mention a few out of the many striking experiments where a higher calorific value or a greater efficiency than the theoretical was obtained.

Hausser made the observation during his experiments to manufacture nitrates, that sometimes efficiencies were obtained that surpassed the theoretical output by 90 to 120 per cent. He also exploded gases in bombs of different sizes and found that with bombs of different sizes different results were obtained.

Similar observations were made by Haber and Koenig in experimenting with electric arcs to manufacture nitric oxide.

Hahn obtained a calorific value 10 to 12 per cent higher than the theoretical calorific value of the fuel in passing a stream of steam into the oil flame.

A good many more reports of this kind can be found in the technical literature.—"Power," March 10, 1925.

COOLING WATER FOR DIESEL ENGINES.

Designers are not agreed as to whether sea water constitutes a suitable medium for cooling the cylinders, cylinder heads, and pistons of Diesel engines installed on board ship. It is argued that when sea water is employed for this purpose there is a possibility of the interior surfaces of the jackets becoming covered with a layer of salt, which, owing to its low conductivity, may lead to overheating, and ultimately to cracking of the part affected. Thus with certain types of engines, fresh water or lubricating oil is used as the cooling medium, and, in order that this may be used over and over again, coolers through which sea water can be circulated have to be installed. The extra weight and cost of this is apparent. It is of interest, therefore, to note that in the report of the operation of a motor-driven tanker recently published in an American contemporary, covering a period of approximately one year, attention is particularly drawn to the experience gained as to the

suitability of sea water for cylinder and piston cooling. The cooling arrangements are held to be entirely satisfactory, despite the fact that the vessel was frequently in very muddy waters and once actually went aground. Upon examination it was found, however, that no solid matter had been deposited in the piping or in the cylinder or piston-jackets, and it is therefore claimed that, beyond a sea-water filter provided with plates having holes 5 millimeters in diameter, no special precautions need be taken when sea-water cooling is employed, even when the vessel has to proceed in waters containing a good deal of solid matter in suspension.—"Shipbuilding and Shipping Record," January 29, 1925.

GEARED DIESEL PROBLEMS.

The rapid developments in Diesel engine propulsion taking place at the present time are proceeding along widely divergent lines, and while the direct Diesel drive predominates largely, several successful installations have been made where a system of speed reduction has been introduced between the prime mover and the propeller, either by electrical, mechanical, or hydraulic means. Electrical speed reduction, or, as it is more commonly described, the Diesel electric system of transmission, is comparatively well known, and the combination had been quite extensively used in shore generating stations for some time before it found application to marine propulsion, so that the major problems had already been, to a great extent, solved. It is with the geared Diesel system of transmission, however, that we are more immediately concerned here.

Probably the first application of geared Diesel transmission for large-sized steamers was made by Germany, and the measure of success achieved is perhaps greater than was contemplated in many quarters. At the time of the Armistice, Germany found herself with a large number of light high-speed submarine Diesel engines on her hands, and the problem of applying these engines to economic commercial use was finally solved in quite a satisfactory manner by the introduction of mechanical reduction gears. The fluctuation in torque usually associated with the single-acting Diesel engine gave rise to considerable doubt in the minds of many practical marine engineers regarding the probable life of mechanical reduction gears, and not a few prominent British authorities expressed the view that such a combination might result in excessive gear stresses and early gearing failures. Several years' successful performance of twin-screw geared Diesel vessels of the *Havelland* and *Muensterland* class of freight and passenger vessels owned by the Hapag have, however, confounded these critics. In these installations the primary or high-speed engine shaft was extended about 30 feet aft through the hollow pinion shaft, giving a flexible drive arrangement. The ratio of speed reduction was low, about 3:1, and the gears have shown no evidence of undue wear.

The success of these installations and the tendency towards increased power for larger passenger vessels led to a natural extension of this principle, and in the latest German twin-screw motor passenger liner, *Monte Sarmiento*, of about 15,000 gross tons, four high-speed single-acting four-stroke cycle engines were installed. Each pair of engines was arranged to drive the propeller through single reduction gearing, one engine being mounted on each side of the large gear wheel, and the same flexible drive arrangement of extended shafts was adopted. Basin trials carried out at Hamburg resulted in the development of enormous torsional vibrations and resonance. Heavy buckling was observed to have taken place in the flexible shafts, and several main bearing bolts of the large gear wheel were fractured. Each pair of engines, port or starboard, is fitted with a common starting

device which is designed to start both units at the same instant, but although starting air is injected to each of the two engines at the same moment, it has been found physically impossible to ensure that both units will pick up at the same instant. This phenomenon, which was difficult to foresee, set up torsional oscillations, which subsequent investigation appeared to indicate might be augmented by the excessive spring effect of the highly flexible shafts. These flexible shafts were accordingly cut out, and each engine was rigidly connected to its pinion through a solid coupling, the only damping effect available being that derived from the heavy 7-ton flywheel on each engine shaft. Later trials were held and torsiongraphs showed that the damping effect of the flywheels was remarkably efficient, and that except for slight variations in starting the torque was comparatively regular. The successful solution of this complex problem would appear to show that in the earlier geared Diesel installations the provision of the flexible shaft drive was a superfluous refinement, although at the time of its inception it was generally believed that no geared Diesel installation could function successfully without a flexible shaft drive.

We, in this country, have never looked kindly upon any system of geared Diesel installations even when the speed reduction was as low as 3:1, and when the prime mover was mounted on one side only of the large gear wheel. The mounting of two high-speed Diesel engines, one on each side of a common gear wheel, manifestly represents a more complex arrangement, and that it has been possible to operate this arrangement, apparently successfully, with a purely rigid drive is distinctly to the credit of the builders. Reports regarding the subsequent performance of this vessel's reduction gears will be awaited with considerable interest.—"Shipbuilding and Shipping Record," January 22, 1925.

CASTINGS FOR DIESEL ENGINES.

Abstract of a Discussion Resulting from an Important Joint Meeting of Metallurgists, Marine Engineers, and Foundrymen Held Recently in Glasgow.

An important conference was held recently in Glasgow under the joint auspices of the Scottish Sections of the Institution of Mechanical Engineers and the Institute of British Foundrymen for the purpose of considering problems connected with the production of reliable castings for Diesel engines. The interest taken in this subject in the Clyde area was reflected in the large number of men in both industries who attended the meeting. Four short papers were submitted, and the various phases of the subject dealt with appealed so strongly to the members of both institutions that it has been decided to hold shortly another meeting for the purpose of discussing the matter still further. The plan adopted in arranging the conference was to have papers read by two prominent members of each Institution, one of whom dealt with the subject mainly from the scientific and the other from the practical point of view, as it related to their particular industries. Prof. A. L. Mellanby dealt with "Temperature Stresses and Working Conditions in Oil Engines"; Prof. A. Campion with "Characteristics of Cast Iron for Oil Engines"; Mr. James Richardson, B.Sc., with "Oil-Engine Design as Affected by Foundry Practice"; and Mr. William Bell with "Oil-Engine Design from a Moulder's Point of View."

STRESSES AND WORKING CONDITIONS.

Dr. Mellanby, in the course of his address, gave several illustrations to show how temperature stresses may arise in pistons and cylinders, and, also, how cast iron may be expected to behave at high temperatures. It is well known, he said, that in the early period of the history of the Diesel engine, cracked liners and pistons were a frequent occurrence. Experience has shown, to a large extent, how to overcome these troubles, but there is always the fear that when cylinders are made larger and the power per cylinder increases, such experiences may be repeated. If, however, the designer can have some information as to the conditions under which the engine has to work, he will be in a much stronger position to guard against possible difficulties. With liners the temperature never reaches so high a point as in the piston, and a maximum temperature of, say, 300 degrees F. at the inner surface of the liner has been measured. Here, again, the temperature difference between the inner and outer surfaces is the source of danger, a point that is now being appreciated by designers. Changes in liner design are constantly taking place, and where temperature and pressure conditions may be severe the placing of large chunks of metal, which act as heat reservoirs and set up large stresses, has been abandoned. While from the stress point of view temperature difference is of importance, it is equally important that the value of the maximum temperature should be known. The cast iron has to stand the stresses induced by the high pressure and temperature difference, it is repeatedly heated and cooled, and it is subjected to wear. It is therefore necessary to know how cast iron will behave under high-temperature conditions.

There are other points that must be considered when the behavior of cast iron at high temperature is receiving attention. Experience has shown that cast iron, which is subjected to alternate heatings and coolings, is liable to undergo changes in volume. This phenomenon is generally classed under the heading of growth, and it is well known that many examples have arisen in practice when engineering details, subjected to alternating high and low temperatures, have so far changed their shape and volume that they have caused considerable trouble. It becomes necessary, therefore, to know with some accuracy to what extent these changes of dimension can take place. There is always the problem of wear to consider, since it is well known that liners have had in some cases to be renewed after a comparatively short life on account of the rapid abrasion by the piston rings. Wear measurements are rather difficult to make in the comparatively short time that is available for a test, but comparisons that have been made by the help of a quite simple abrasion test have shown that the wearing properties of cast iron may differ quite as much as their growth properties. It is, however, of interest to note that resistance to wear may be associated with resistance to growth. This, then, brings us to the stage when we can make an appeal to the metallurgist. We can now tell him what are the worst conditions under which cast iron has to work, and we can ask him to tell us how to produce a metal that will retain its strength at the maximum temperature we may expect, that will not increase in size after a limited period of service, and that will resist wearing away under the rubbing action of the piston rings.

CHARACTERISTICS OF CAST IRON FOR OIL ENGINES.

Professor Campion, in dealing with this subject, said: The successful development of the internal-combustion engine depends in a large measure upon the ability of the metallurgist and founder to produce castings suitable for the components, especially the cylinder, cylinder cover, liner, piston, and piston rings. The purely metallurgical aspect of the problem is of importance because only special sorts of cast iron can withstand the temperature

and stress conditions which obtain in oil engines. The properties and characteristics of these special qualities of cast iron differ in many respects from those of irons ordinarily employed for steam or general engineering castings, and the complicated nature of many of the castings demands from the foundryman great skill and initiative in devising the best methods of preparing the mould, placing and securing cores, venting, etc. It requires very careful consideration to determine the type of runners to be used and the position in which they are to be placed. An intricate casting requires that the metal used shall be capable of running into the thinnest portions and retaining its greyness; at the same time it must make the thick parts dense and close grained.

In considering the nature of the metal to be used it is not proposed to give detailed analyses of iron for any particular purpose, as these will naturally vary according to the size and intricacy of the casting, but rather to indicate the general metallurgical principles which have to be applied in determining the type of the metal to be used. The first requirement is that the casting shall be perfectly sound, as even a minute pin-hole in an oil-engine cylinder or liner will render it useless. The term soundness has a very special sighificance when applied to these castings, owing to the heavy duty they have to perform under severe conditions. Slight flaws or imperfections, which would be of small moment in ordinary castings, would be fatal in a casting for an oil engine. The chief properties required are: soundness, the metal must be close-grained, with strong crystalline cohesion, and there must be freedom from draws or blowholes. It must be of high tensile strength and other physical properties, and show constancy of form and dimensions, with high resistance to wear, and no cracking when submitted to high or fluctuating temperatures. The main factors concerned in the production of cast-iron materials having these characteristics are:—

(1) Composition.
(2) Melting and casting conditions.
(3) Rate of cooling and solidification.
(4) Structural arrangement of the components.

MELTING AND CASTING.

The melting is probably best done in a reverberatory furnace, as it can be better controlled and the composition may be more easily and certainly adjusted and the desired casting temperature obtained, but good results can be obtained in a cupola provided that it is of suitable design and under complete supervision. The casting temperature and the rate of soldification and cooling, according to the thickness and contour of metal, must be taken into account when deciding the composition to be employed in any given casting, as these are factors which exert much influence in fixing the constitution and structure of the metal upon which largely depend its properties. The ultimate chemical analysis as usually stated shows only the proportions of the elements present, but it is necessary to know the form in which they exist, and how they are distributed through the whole mass.

The structure of oil-engine metal should exhibit a matrix consisting mainly of pearlite with the free carbon or graphite in small particles evenly disseminated through it. The phosphide should also be regularly distributed in small patches, or in the form of a mesh. Large plates of graphite, or large and segregated areas of phosphide, are to be avoided, as both are contributory causes of growth and deterioration of strength. Casting and cooling rates influence the arrangement of the constituents.

It is commonly assumed that there should be sufficient combined carbon to make the matrix wholly pearlitic with or without free cementite in order to give a certain amount of hardness, but it is open to discussion as to

whether this is the most desirable structure. Hardness is no criterion of wearing qualities; in fact, the hardest material often has the lowest resistance to abrasion, and has a tendency to crack under heavy or suddenly applied loads. What is wanted is a tough metal that can spread to a sufficient extent to form a highly burnished surface. If free cementite or large patches of phosphide be present, they are liable to break off and form a grit which increases wear. It appears that the most satisfactory result is obtained when the combined carbon is sufficient to give a matrix which is not quite all pearlite, a very small quantity of free ferrite. Pearlite may vary in form, and is most satisfactory when it takes the form of very fine laminæ of cementite and ferrite. The method of melting a mixture of steel scrap and pig-iron is to be recommended for the production of metal with the desired structure giving high strength, durability, and resistance to heat conditions. The material is known as "semi-steel," and has a particularly close and compact structure, machines well and is capable of taking a high polish. Its preparation, however, demands most careful attention to detail, measurement, or weighing of coke, pig-iron, scrap and air, together with skilled attention to all melting operations, which must be effected in a well-proportioned cupola. The structural composition and arrangement of the components are of the first importance in securing the desired properties and characteristics in metal to be used in oil-engine castings, and can only be obtained by strict attention to details and exact control of every operation. The difficulties of making intricate castings to meet such severe conditions are very great, and can only be surmounted by complete and cordial co-operation of all concerned—designer, metallurgist, and foundryman.

OIL ENGINE DESIGN AS AFFECTED BY FOUNDRY PRACTICE.

Mr. James Richardson said: In the question of oil engines, particularly those for marine purposes, constructors in this country are faced today with more severe competition than ever before in the history of this movement, and in order to meet efficiently the absolute necessities of the future, earnest collaboration between all parties concerned—the designer, the foundryman, and others—is essential. It is unquestioned that the oil engine makes greater demands upon the foundry than any other type of prime mover, since not only have high physical loads to be withstood, but stresses due to intense temperature may be combined with these loads. I have prepared several diagrams to illustrate what occur to me as the principal points in this connection. Fig. 1 shows, with dimensions, two designs of Diesel engine cylinders. That on the left is a Continental design. The variation in wall thickness will be noticed. This design is there regarded as a satisfactory solution of the problem, little or no difficulty being experienced in getting the requisite hard material on the inside of the inner barrel of the cylinder to withstand the friction of the travelling piston rings. British practice demands more even thicknesses of material, and in my experience sufficiently hard metal on the inside cannot be obtained in this country with the Continental design, so that the designer is faced with providing for an extra weight of 33 per cent or an extra cost of not less than 100 per cent. Must the British designer perpetually be faced with this disability? Do considerable variations in thickness impose such difficulties on the foundry that such castings are a commercial impossibility? Can scientific cooling of the casting in the mould, to give chilling of the special surfaces in order to obtain the requisite degree of hardness and wearing properties, not be introduced as a commercial proposition? The same point is further exemplified in the Diesel compressor cylinders, as shown in Fig. 2, the extra weight due to maintaining relatively even thickness throughout, without what would here be regarded as thin metal and the insertion of a special liner, being 33 per cent with 60 per cent increased cost. In respect of cylinder liners, as shown in

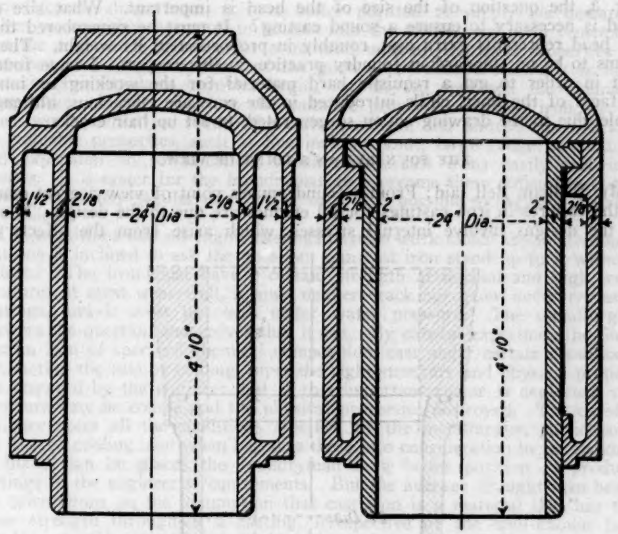


FIG. 1.—TWO DESIGNS OF ENGINE CYLINDERS.

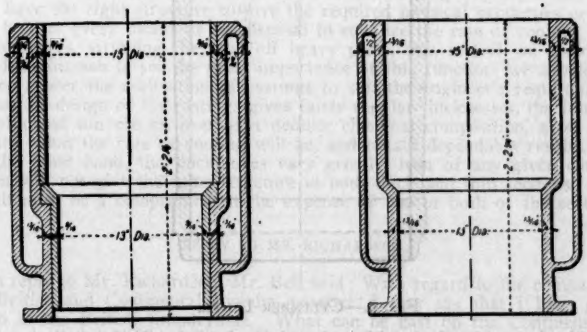


FIG. 2.—TWO DESIGNS OF COMPRESSOR CYLINDERS.

Fig. 3, the question of the size of the head is important. What size of head is necessary to ensure a sound casting? It must be remembered that the head represents extra cost, roughly in proportion to its weight. There seems to be no standard in foundry practice, in this respect. I have found that in order to get a requisite hard material for the working or inner surfaces of the liner, chills introduced in the core are efficacious, although liable, due to the drawing action so generated, to set up hair cracks.

THE FOUNDRYMAN'S POINT OF VIEW.

Mr. William Bell said: From a foundryman's point of view a great many of the failures in iron castings for oil engines are due to the design. Many of the designs involve internal stresses, which arise from the effects of

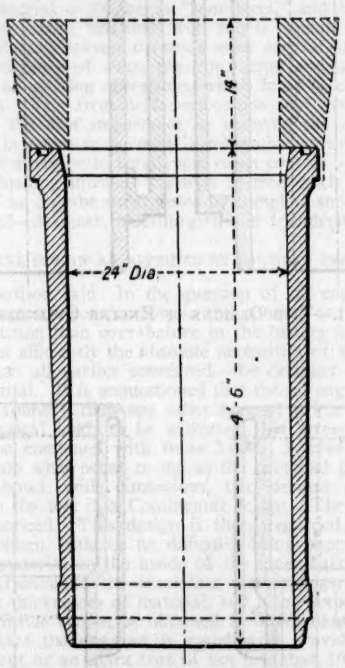


FIG. 3.—CYLINDER LINER.

crystallization and of graphite, deposited during solidification, causing unequal contraction, porous and weak castings. This is undesirable at any time, but more especially in castings that have to be subjected to repeated heatings. Now, in the manufacture of castings for oil engines, such as cylinders, covers and pistons, the foundryman's difficulties arise from the material cast into the mould more than from the actual moulding, and although the demands of the engineer are increasing year by year for more complicated castings, the foundryman of today, with his greater store of

knowledge to draw from, is in a better position to supply his demands. When we consider the metal to be cast into the moulds, we must remember that the engineer is striving for a material with all the good properties of cast iron, and also with some of the good properties of steel. It is here that the foundryman's troubles begin, for, as we approach the chemical composition of steel, we lose the valuable properties of cast iron, or, in other words, when we reduce the carbon, silicon, and phosphorus, we lose the valuable properties, such as low melting point, large range of fluidity, and expansion on solidification, which makes cast irons easily cast into moulds. It is easier for the foundryman to overcome these difficulties if the casting has fairly regular thicknesses, or if it is possible to regulate the rate of cooling.

The conditions that oil-engine castings have to work under are so strenuous that one is inclined to ask the question, Can cast iron stand up to it without failure? The iron must have a certain strength at normal and high temperatures, it must wear well, it must neither crack nor grow under repeated heatings, and it must not leak under water pressure. The metallurgist answers the question and proves that it can. By careful experiment he finds that an iron of specified chemical composition, cast under certain conditions, *i. e.*, noting the rate of cooling, gives the right structure and physical properties required by the engineer, but if this important factor is neglected, the structure may be coarse and the physical properties destroyed. The careful designer notes all the conditions specified by the metallurgist, particularly the rate of cooling, and when he takes these into consideration in the making of his design he places the foundryman in a better position to produce castings to the engineer's requirements. But the average draughtsman bases his calculations on the assumption that cast iron is a material that has the same strength throughout a casting, irrespective of the well-known fact that it is possible to cut two test pieces from the same casting and get results as high as 20 tons per square inch and as low as 4 or 5 tons per square inch —this difference being due to the different rates of cooling in the two parts from which the tests were cut. The foundryman knows, of course, that this is one of the most important factors in determining whether a cast iron will have the right structure to give the required physical properties or not, and he uses every means at his disposal to equalize the rate of cooling, such as denseners, stripping the sand off heavy parts, etc., and if we could get the draughtsman to see the great importance of this function, we should get a step nearer the realization of castings to suit the engineer's requirements. When the design of the castings gives fairly regular thicknesses, the foundry metallurgist can use an iron of a definite chemical composition, after estimating what the rate of cooling will be, and obtain dependable results. If, on the other hand, the thicknesses vary greatly, iron of any given composition will not give the same structure in both thick and thin sections. The result must be a compromise at the expense of one or both of the sections.

REPLY TO MR. RICHARDSON.

In reply to Mr. Richardson, Mr. Bell said: With regard to the comparison of British and Continental foundry practice, I may say that I have great faith in the British foundryman. What can be cast on the Continent can be cast in Britain. The difference in the rate of wages and the hours worked per day may give the Continental foundryman an advantage in the cost of production, but I believe the advantage ends there. The British engineer is respected all over the world for his high-class workmanship, and the British foundryman has made it possible for him to hold that position. Fig. 1 shows the designs of Diesel engine cylinders—the British one is built up of three castings, while the Continental one is cast in one piece. When we consider

the nature of cast iron, the size of the casting, and the physical load to be withstood, this design has nothing to recommend it, but if the cover is cast separately—and I believe from an engineering point of view this would be an advantage—the rest of the casting should present very little difficulty to the British foundryman. The variation in thickness of the two walls, 1½ inches to 2⅜ inches, should not make it impossible for the British foundryman to cast with a reasonable amount of hardness in the barrel. The outside thickness on such a casting as this will always contract more than the inside, internal stresses are liable to be set up, and a stronger casting will result from a reduction of the inside thickness and increasing the outside without materially interfering with the weight. The air and exhaust ports are not shown on this design, and it is generally these details that cause unequal thicknesses. Fig. 2 shows two designs—air compressor cylinders. From a moulder's point of view, the Continental design would be the easiest to mould, and the greater space between the two thicknesses would allow a stronger jacket core to be used. On the other hand, if we take the British design and increase the space between the outer and inner walls, keeping the thicknesses the same, many of our foundries could produce such a casting with the inside close grained enough to do without a liner. With regard to Fig. 3, the question may be asked, What size of a head is required on a liner of this description? If this casting were cast without a head, the top part, being heavier, would solidify last. The crystals start to grow at right angles to the cooling surface, gradually getting larger as they near the center, the bottom feeds away the liquid metal leaving the heavy part at the top porous.—"The Marine Engineer and Motorship Builder," February, 1925.

TAKING THAT BARK OUT OF THE EXHAUST.

Why One Oil Engine Has a Noisy Exhaust While Another Operates Smoothly—Effect of Poor Exhaust Connections on Engine Performance—Means of Making Exhaust Quiet.

By Hiram Percy Maxim.

A serious handicap confronting the manufacturer and the user of oil engines is the objectionable noise made by the exhaust. As a consequence, it is by no means seldom that a complaint develops into a court action whereby some adjoining property owner cites the oil-engine owner as maintaining a nuisance, in that for blocks around the plant the sleep of dwellers is broken by the machine-gun bark of the engine. Fortunately, the difficulty is easily remedied by an inexpensive alteration in the exhaust connections.

In providing for the exhaust of large oil-engine installations, it has been thought that all that was necessary was to provide a large expansion chamber so that the exhaust gases would be given an opportunity to expand quickly. The idea quite generally prevails that the expansion of the gases in a large chamber lowers the back pressure and muffles the exhaust noise. This can be a very wrong idea, and it can be the cause of much trouble and unnecessary expense.

The two causes for the wrong impression mentioned come from the failure to realize that a large exhaust conductor and expansion space does not always mean low back pressure, and the failure to realize that noise is one thing and gas flow another very different thing. I have been called upon many times to advise owners of power plants how best to get over exhaust difficulties and I have seen tremendous sums of money thrown away because of the failure to grasp the two points mentioned. For example, a six-cylinder oil engine of 300 horsepower had been installed in a certain plant,

and the engine performance had not been entirely satisfactory on account of back pressure. In addition the noise of the exhaust could be heard for a mile away from the plant. The exhaust system consisted of a large exhaust pot, giving quick expansion and a 60-foot exhaust stack.

When operating conditions became so bad that something had to be done, a concrete pit was built at considerable expense to connect the exhaust pot with the stack. To the astonishment of the owners this change made the engine operate much worse and considerably increased the noise.

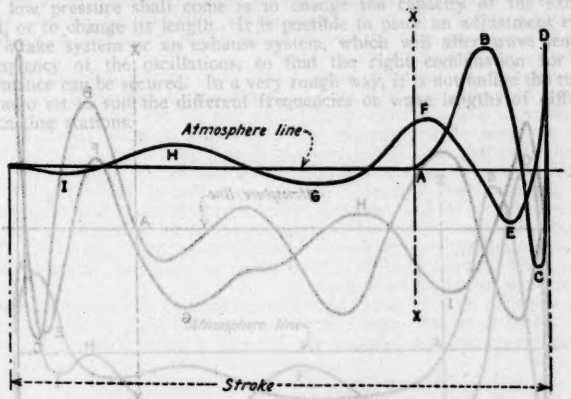


FIG. 1.—PRESSURE WAVES IN EXHAUST LINE.

From the history of the case it was evident that the "patient" was suffering from an acute case of bad tuning and resonance. The bad tuning resulted from the accidental dimensions that happened to be established for the concrete pit, which just chanced to be right for bringing the high-pressure point of an exhaust wave at the instant the exhaust ports closed. This gave back pressure and bad engine performance, notwithstanding the increased size of the exhaust system. The resonance, whereby the noise of the exhaust was amplified, was probably due to the same thing that causes the amplifying of the noise of the Fourth of July firecracker when it is exploded in the barrel.

To get a grasp of what was going on in that concrete pit, it is necessary to understand what happens in the exhaust of an oil engine. It happened that the particular installation in question was a two-stroke-cycle engine. An indicator diagram taken of the pressure variations in the exhaust pot, which was connected to the concrete pit, appears in Fig. 1. The exhaust port opens at line XX, and the pressure rise resulting from the release of the exhaust gases from the cylinder starts at A and rises to B, and proceeds to oscillate from there on. It will be noticed, first of all, that the pressure is oscillatory in character. That is to say, there is a wave motion and there are points where at a certain instant the pressure is above atmosphere and there are other points where the pressure is below atmosphere.

It will be seen from an examination of Fig. 1 that the exhaust port closed at F, one of the points of high pressure in the exhaust system. It is apparent that the frequency of the waves is a measurable quantity. From this, it follows that if some kind of tuning, or control of frequency, could be

secured, we would be able to make the low point of a pressure wave coincide with the closing of the exhaust port. This would give very good engine performance, for the reason that the scavenging would be good.

In order to understand this phenomenon of tuning, it might pay to consider this curious tendency to oscillate. Any sudden release from a high pressure seems to be oscillatory in character whether the energy released is gaseous, liquid or electric. If the resistance in the conductor through which the discharge occurs is high, the oscillations are quickly damped out. The tendency that creates the oscillation is the tendency to overdischarge, or

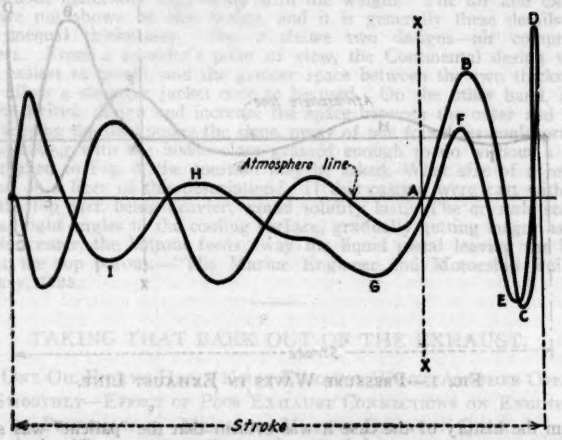


FIG. 2.—CHANGE OF CONNECTIONS IMPROVED PRESSURE CONDITIONS.

overswing. The pendulum, when released, overswings. When it swings back, it overswings back. This continued overswinging we call "oscillating." Unless we understand exactly what is going on, these oscillations are likely to cause much trouble. On the other hand, when we understand them, we are able to make them assist us. This is what is called "tuning." As the diagrams show, it is perfectly simple to indicate the high points and the low points in the oscillations. It is therefore apparent that it is desirable to control them so that we can make a low point coincide with the closing of an exhaust port. To carry the matter to the field of suctions, it can be seen that it is possible to make a high point coincide with the closing of an intake port.

INDICATOR SHOWS PRESSURE WAVES.

In Fig. 1 the exhaust pressure being released at A, B shows a high point, C a low point, D the next high point, and E, F, G, H and I alternating low and high points. It is apparent that the high point F practically coincided with the closing of the exhaust port. This gave high temperature exhaust readings, a sure sign of back pressure and poor engine performance.

Turning to Fig. 2, where a change was made, we have the same pressure release at A, a high point at B, a low point at C, a high point at D, a low

point at E, but the high point at F has been brought forward and the exhaust port has not yet closed. The pressure wave has fallen to approximately atmosphere at the instant of closing of the exhaust port. The engine performance was better.

More of the same thing gave the diagram shown at Fig. 3. The pressure is released at A, B is a high point, C a low point, D a high point, and this time the low point E is made to coincide approximately with the closing of the exhaust port. Splendid engine performance immediately resulted.

The means by which we are able to control just where a high pressure and a low pressure shall come is to change the capacity of the exhaust system, or to change its length. It is possible to place an adjustment either in an intake system or an exhaust system, which will alter wave lengths, or frequency of the oscillations, so that the right combination for best performance can be secured. In a very rough way, it is not unlike the tuning of a radio set to suit the different frequencies or wave lengths of different broadcasting stations.

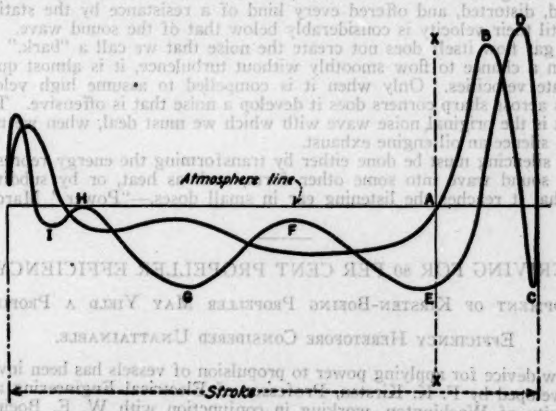


FIG. 3.—FINAL ADJUSTMENTS GAVE THIS PRESSURE CURVE.

Thus we see how ill luck can bring about just exactly the combination of dimensions in a concrete pit to give the highest point in an exhaust wave, at the instant that the exhaust ports close. To correct this a radical change is usually necessary in the concrete pit or expansion tanks, which may be very expensive, and with grave doubts as to the efficiency of the arrangement.

Turning to the other difficulty, that of noisy exhaust, why was it that the introduction of the large concrete pit increased the exhaust noise? The answer is: For the same reason that the announcer at a football game transforms his voice into the voice of a superman by making use of an expansion chamber known as a megaphone.

The reason that the megaphone amplified the announcer's voice, was because it set into oscillation a larger weight of air before liberation into the surrounding atmosphere. It is a complicated matter to explain, but it has so many every-day examples that we are able to grasp. We call it "resonance," and when we place the tuning fork on the cigar box or the

violin bridge on the thin wooden box that we call the body of the violin, we make use of it. The trouble is that we forget it when we install an oil-engine exhaust system, and the first thing we know, we are doing what corresponds to putting a megaphone on the exhaust to amplify it, instead of silence it.

WHAT CONSTITUTES A NOISE.

The noise wave is a zone of compressed air followed by a zone of rarefied air, and it is one of nature's laws that such a wave spreads out in all directions at a constant velocity of approximately 1100 feet per second. It continues to spread out until attenuation finally makes it inaudible to the human ear, the air offering almost no resistance.

The gas flow, on the other hand, is subject to entirely different laws. At the very beginning of the burst of the column of exhaust gases into the atmosphere, it has a velocity many times that of the sound wave, and yet before the gases have advanced any substantial distance, they have been checked, distorted, and offered every kind of a resistance by the stationary air, until their velocity is considerably below that of the sound wave.

The gas flow itself does not create the noise that we call a "bark." If it is given a chance to flow smoothly without turbulence, it is almost quiet at moderate velocities. Only when it is compelled to assume high velocities or pass across sharp corners does it develop a noise that is offensive. Therefore, it is the original noise wave with which we must deal, when we undertake to silence an oil-engine exhaust.

This silencing must be done either by transforming the energy represented by the sound wave into some other form, such as heat, or by subdividing it so that it reaches the listening ear in small doses.—"Power," March 10, 1925.

STRIVING FOR 80 PER CENT PROPELLER EFFICIENCY.

Development of Kirsten-Boeing Propeller May Yield a Propulsive Efficiency Heretofore Considered Unattainable.

A new device for applying power to propulsion of vessels has been invented and developed by F. K. Kirsten, Professor of Electrical Engineering at the University of Washington, working in conjunction with W. E. Boeing of Seattle. This invention, called the Kirsten-Boeing propeller, has undergone extensive tests on a 38-foot motor boat.

It operates on radically different principles from the conventional screw propeller. Perhaps the best idea of the actual construction and appearance of the K-B propeller can be obtained from the diagram and illustration reproduced with this article. The mechanism is comparatively simple. It consists of a large disc installed on the bottom of the boat and driven by spiral bevel gears from the engine. Extending downwards through this disc are several blades which not only revolve with the disc, or rotor, but themselves are geared so as to rotate independently, in the manner of a sun and planet motion.

The thrust upon the water is produced by these blades through the combined motions. First, the axes of the blades are caused to move in a circular path with a uniform motion, the plane of the circular path being at right angles to the axes of the blades. Second, while moving in the circular path the blades are caused to rotate on their own axes, this motion also being uniform. The motions are so related that during the time each blade, starting from a given point, makes one revolution around the center of disc, it must make one half a rotation on its own axis.

KIRSTEN-BOEING PROPELLER UNIT.

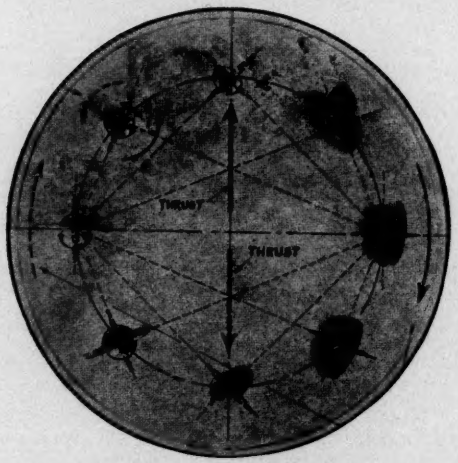


DIAGRAM OF BLADE THRUST.

Full line arrows relate to one direction of motion; dotted arrows relate to the opposite direction.

A report issued by the builders of the K-B propeller explains their operation as follows:

"A condition resulting from these motions (the two motions of the blades on the rotor) is that the plane of each blade (*i. e.*, a plane which passes through the axis and edges of the blade) will pass through one point, this point being located in the circular path on which the blades move and which, when set by the controls, is stationary with respect to the motion of the blades.

"A second condition which results from the two motions of the blades is that, if a line be drawn through the point on the circular path and also through a point diametrically opposite on the path, the corresponding instantaneous positions of each blade on opposite sides of this line will be symmetrical with respect to it. This line is called the axis of symmetry, and the thrust produced by the blades while being moved as described is always at right angles to this axis and parallel to the plane of the circular path, the direction of the thrust with respect to the sides of the axis being determined by the direction of rotation of the blades around the center of the circular path.

"The axis of symmetry can be turned about the center of the circular path, the center acting as a pivot; hence the direction of the thrust can be turned to any direction desired. It is apparent on following the motions of the blades that the axis of each blade crosses the axis of symmetry twice in one revolution and, at the point on the circle where all of the planes of the blades meet, each blade, at the instant it passes this point, will become tangent to the circle. At the second point the plane of the blade coincides with the axis of symmetry."

It is apparent that with such a mechanism, no rudder or any of the customary steering apparatus will be required, because the boat can be steered by shifting the direction of the thrust. Similarly, no reverse gear is needed, because the boat can be driven astern by throwing the thrust forward. In other words, propelling and steering are taken care of by one mechanism, simplifying control of the vessel.

The advantages claimed for the K-B propeller grow mainly out of the increased maneuverability it gives the boat, a saving in operating expense due to greater efficiency and a simplification of hull construction.

Since with the K-B propeller the steering of the vessel can be accomplished by changing the direction of thrust of the propeller itself, the pilot has remarkable control over the boat. For any size craft the control is entirely in the hands of one man. The only operation required on the engine is to increase or decrease the revolutions as the engine runs in the same direction at all times.

With the high speed test boat it was found possible to turn in a circle of 100 feet radius while under full power. In making a turn the boat banks inward instead of outward as with a screw propelled boat. The boat can be stopped in two lengths and started full speed astern.

The K-B propeller is feasible for twin installations, according to its inventor. Either two engines may be used or two wheels may be geared to the same engine. With a twin installation, the maneuvering advantages of the propellers are very marked. There is practically no vibration and the propellers have a marked stabilizing effect on the hull.

The basis upon which the inventor claims reduced operating costs in the use of the K-B propeller are derived from test runs made with the 38-foot motor boat in which the propeller was first used. The boat is equipped with a 200 horsepower marine engine developing its rated horsepower at 1800 revolutions per minute. The motor is connected to the propeller by means of a shaft through two flexible couplings, one at the motor and one at the propeller. A clutch is provided on the motor to disengage the motor from the propeller, but the reversing mechanism is not used.

The present propeller has been in service since April 7, 1923, and has propelled the boat a distance of 2500 miles, in both fresh and salt water. The propeller so far has not given the slightest trouble and has never failed to complete any trip required of it. On a number of its trips the boat has come into contact with floating logs and boards and bent the blades, but the propeller itself was never damaged. With this machine the operation of taking out a bent blade and inserting a new one is only a matter of a few minutes' time. It is done while the boat is in the water, it being unnecessary to drydock the vessel.

In addition to the mileage made, the propeller has been subjected to many other severe conditions, such as the sudden reversal of thrust and the quick application of full power. After being taken down on having run the first 1200 miles, the parts were found scarcely worn at all and all the gears were in good condition.

On several tests made on Lake Washington, Seattle, over a measured course, the slip of the propeller was found to be 20.1 per cent which, on the basis of tank experiments was deduced to be equivalent to a propeller efficiency of around 80 per cent, a gain of about 15 per cent over the efficiency of the screw.

Having no shaft projecting outside the hull and no propeller blades rotating in a vertical plane, it is not necessary with the K-B installation abruptly to draw in the lines of the stern. They can in general be made to run out almost straight, thus simplifying the construction and increasing the space within the hull.

Efficiency tests of a model K-B propeller were made at the Navy Yard, Washington, D. C., under the direct supervision of Rear Admiral D. W. Taylor, retired. Because of the time limit placed upon the use of the model testing basin the tests originally contemplated could not be carried out so that, unfortunately, no data can be given from tests made with the propeller placed in a model hull.

According to Admiral Taylor's report the diameter of K-B propellers would be rather large to obtain a greater efficiency than the screw for slow-speed vessels, such as cargo vessels, but to quote from the latter part of his report: "For vessels of the wide flat stern type and fairly high speed it seems possible to fit K-B propellers with efficiency markedly superior to that of the screw propeller."

One of the next steps of the Kirsten-Boeing Engineering Company is the building of a seventy-five-foot boat exactly similar to the type the Government is having made for Coastguard rum chasers. This vessel will be equipped with the same engines used by the Coastguard, but in it will be installed twin Kirsten-Boeing propellers. The craft will then be used to demonstrate the efficiency of the new propellers.

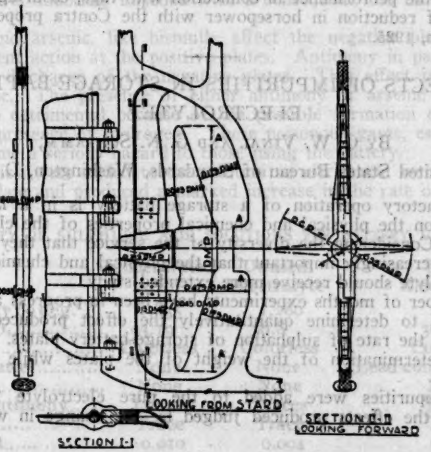
It will demonstrate, according to Professor Kirsten, that such a craft can be operated for one-half the fuel cost of driving screw propellers, that the new type propeller is a rudder as well as a propulsion mechanism, that its upkeep is virtually nil, and that the vessel can be maneuvered with the ease and facility of an automobile.

This style of propeller is to be installed and tested on the Navy dirigible *Shenandoah*, according to Seattle reports.—"Motorship," April, 1925.

THE STAR CONTRA PROPELLER.

We have noted recently in these columns that the Star Contra propeller has been fitted to certain motor ships. It will come as a surprise to most people to learn that within the past three years 124 vessels of over 436,000 tons, with machinery of 166,000 indicated horsepower, have been fitted with the new form of propeller.

Messrs. James Pollock, Sons and Co., Ltd., 3, Lloyd's Avenue, London, E.C.3, have just issued a very valuable and extremely well-produced booklet dealing with this propeller, giving details of its principles of action and the results which have been achieved with it in practice. It will be remembered that the main principle of operation of the Contra propeller is the provision of a means whereby the tangential movement of the propeller stream is converted into axial acceleration. The claims made are that the propeller is protected, that the vessel will develop the same speed, with 7 per cent to



ARRANGEMENT OF THE STAR CONTRA PROPELLER WITH THE BEST FORM OF STERN FRAME.

10 per cent less power, or, alternatively, will have an increased speed for the same indicated horsepower, that the maneuvering is improved, that the steering is better with a smaller turning radius, and vibration is reduced.

The following interesting comparison is given between the motor ships *Silverpine* and *Silverlarch*, both built by Messrs. Swan, Hunter, and Wig-

	Silverpine (Without c. p.)	*Silverlarch* (With c. p.)	Comparison
Draft, mean	12 feet, 10 inches	12 feet 8¼ inches	.....
Displacement (tons)	5576	5526	.....
Displacement Coefficient	.696	.695	.....
Speed, 1st trial	10.76	11.05	Increase 2.7 per ct.
Speed, 2nd trial	11.11	11.85	Increase 6.66 per ct.
R.P.M., 1st trial	99.8	99.7	Decrease .1 R.P.M.
R.P.M., 2nd trial	105.4	107.25	Increase 1.85 R.P.M.
Slip, 1st trial, per cent	7.4	4.6	Decrease 2.8
Slip, 2nd trial, per cent	9.4	4.8	Decrease 4.6
B.H.P., 1st trial	1750	1670	Decrease 4.57 per ct.
B.H.P., 2nd trial	2070	2085	Increase .725 per ct.

ham Richardson, Ltd., for the Mount Steamship Co., and identical in all respects. They are 400 feet in length, and are each fitted with a 2250 indicated horsepower Neptune oil engine.

It will be seen that, with an increase of 2.7 per cent in the speed, the power needed when the Contra propeller is fitted was 4.37 per cent less. Similar comparisons are given with steamers before and after fitting a Star Contra propeller, showing that the claims made by the builders are borne out in practice. An interesting chart is published in the brochure dealing with the performance in connection with tugs, ensuring a substantial percentage of reduction in horsepower with the Contra propeller.—"Motor Ship," March, 1925.

EFFECTS OF IMPURITIES IN STORAGE-BATTERY ELECTROLYTE.*

By G. W. Vinal and G. N. Schramm,

United States Bureau of Standards, Washington, D. C.

The satisfactory operation of a storage battery is in a large measure dependent upon the physical and chemical properties of the electrolyte that it contains. Considering the diversity of the service that they have to perform, it is increasingly important that the physical and chemical properties of the electrolyte should receive more extended study.

For a number of months experiments have been in progress at the Bureau of Standards to determine quantitatively the effect produced by various impurities on the rate of sulphation of storage-battery plates. The method involves a determination of the weight of the plates while suspended in solution.

Various impurities were added to the pure electrolyte 1.250 specific gravity, and the effects produced judged by the change in weight of the plates.

IMPURITIES AFFECTING THE NEGATIVE PLATES ONLY.

The impurities that affect the negative plates only may be divided into two classes:

A. Impurities that are deposited quickly in the metallic state upon the negative plates and produce appreciable gassing. These include platinum, copper and silver. A closed circuit exists between the underlying lead of the plate and the impurity that is deposited upon it. Lead sulphate is formed in proportion to the quantity of electricity flowing and the plate gains in weight. Hydrogen is liberated at the surface of the impurity. The local action produced by these impurities proceeds at a fairly rapid rate until the ultimate capacity of the plate is exhausted. A considerable part of silver and copper, which is deposited on the plates as a spongy or tree-like mass, subsequently falls off so that the gain in weight of the plates represents chiefly lead sulphate. These impurities cannot be eliminated by changing the electrolyte in the battery, but their effect may in some cases be mitigated. Platinum is one of the most deleterious of impurities. Extremely small amounts are sufficient to produce rapid sulphation of the plates. Copper produces less effect.

B. The second class of these impurities includes those chemical compounds that are reduced more slowly at the negative plates and result in little, if any, perceptible liberation of hydrogen. In some cases these impurities can be eliminated from a battery by replacing the electrolyte.

* Abstract from a paper, "Storage Battery Electrolytes," presented at the Midwinter Convention of the A. I. E. E., New York City, February 9 to 13, 1925.

Bismuth presents an interesting example of the reduction produced at the negative plates accompanied by the deposit of the bismuth itself as a brown powder on the plate. Bismuth trioxide reacts with sulphuric acid to form bismuth sulphate, and this, in turn, is reduced at the negative plate to bismuth with the formation of an equivalent amount of lead sulphate. No appreciable effect was produced by the bismuth on the positive plates. The local action produced by the bismuth that is deposited in the pores of the negative plates is relatively slow, but the diffusion of the electrolyte into the plates is doubtless impeded with a consequent loss in the available capacity.

Antimony and arsenic, like bismuth, affect the negative plates, but are without apparent action at the positive plates. Antimony in particular produces a rapid discharge of the negative plates. This effect is less in the case of arsenic. The presence of either antimony or arsenic in the electrolyte is also detrimental because of the possible formation of stibine or arsine in the presence of hydrogen. These poisonous gases, escaping from the cells, become a serious hazard to those using the battery.

Nitrates which were added to the solution as nitric acid were reduced at the negative plate and produced a marked increase in the rate of sulphation.

PURITY OF SULPHURIC ACID SOLUTIONS FOR BATTERY USE.

	Concentrated Acid	Unused Electrolyte	Used Electrolyte
Specific gravity 60 deg. F.	1.835	1.280	1.280
Per cent H_2SO_4	93.19	36.8	36.8
Color	Colorless	Colorless	Colorless
Suspended matter	None	None	Lead compounds only
Platinum	None	None	None
Arsenic and antimony	Traces	Traces	Traces
Manganese	Trace	Trace	Trace
Iron, per cent	0.010	0.004	0.015
Copper, per cent	0.005	0.002	0.005
Nitrates and nitrites	Traces	Traces	Traces
Chlorides calculated as Cl.	Trace	Trace	Trace
Organic matter	Trace	Trace	Trace
Sulphurous acid	Trace	Trace	None

Even so small a quantity as 0.001 per cent produced a measurable result. Small quantities of nitrates probably do little permanent damage, as they are gradually eliminated from the cell as oxides of nitrogen or reduced to ammonia. Nitrates were without effect in the experiments or pasted positive plates, but their use as a corrosive agent in forming plante plates from sheet lead is, of course, well understood.

IMPURITIES AFFECTING BOTH POSITIVE AND NEGATIVE PLATES.

Iron is perhaps the most common impurity in storage-battery electrolytes. It is oxidized at the positive plate and reduced at the negative plate without depositing on either ad infinitum. Since it stays in solution it can be eliminated by changing the electrolyte. Manganese is more detrimental to the positive plates than to the negatives.

Chlorine is a detrimental impurity for both the positive and negative plates although in small quantities its effects are more pronounced on the positives. Chlorine is liberated at least in part from the cell, but others have stated that a portion of it is oxidized to perchloric acid and this remains in the electrolyte.

IMPURITIES AFFECTING POSITIVE PLATES ONLY.

Impurities of this class are organic compounds. In the experiments with acetic acid the effects produced were smaller than were anticipated, and several more portions of acetic acid were added to the same jar at intervals without much effect.

LOCAL ACTION PRODUCED BY COMBINATION OF IMPURITIES.

The effects produced on negative plates by combinations of impurities which, taken singly, produced less effect than when present in combination were determined. The action of such combination as tungsten and copper exceeded materially the effects of either of these materials singly.

In addition to the experiments on tungsten and copper, combinations of copper with other impurities such as mercury, molybdenum, zinc, arsenic and antimony were tried. In all these cases it was found that the rate of sulphation of the negative plates were greatly accelerated. These results are significant in showing that it is important to limit the percentage of copper that may be present in the electrolyte to the smallest reasonable figure.

In the course of the experiments combinations of tungsten with arsenic, antimony, and several other impurities were tried, but the tungsten produced no unusual effect except when in combination with copper.

IMPURITIES PRODUCING LITTLE OR NO EFFECT.

In the course of the experiments a number of impurities were tried that produced little or no effect on either the positive or negative plates. These included sodium, calcium, magnesium, aluminum, zinc, cadmium and mercury.

At various times sodium and magnesium sulphates have been suggested as an addition to sulphuric acid of the ordinary electrolyte to decrease the sulphation of the plates. Results obtained when these materials were added to 1.250 specific gravity electrolyte indicate that these substances are without effect on the rate of sulphation in concentrations up to 5 per cent, and no benefit is to be derived by adding them to ordinary solutions. Others have claimed that the presence of sodium sulphate and similar substances is harmful, resulting in the disintegration of the negative plates.

Specifications for battery acid have been issued by many different agencies, and a comparison of them shows wide divergence in the impurities that are listed and the maximum amounts that may be considered permissible. If suitable specifications for sulphuric acid for use in batteries can be formulated and receive general recognition, it is likely that they will find use also in other industries. The amount of concentrated sulphuric acid used per year for batteries in this country is probably in excess of 30,000,000 pounds.

If the amount of impurities allowed by the specifications is made too small, serious difficulty may be encountered in finding acid sufficiently pure to meet them. On the other hand, the specifications must limit the impurities to satisfactory battery operation.

Specifications are usually drawn to apply to the concentrated acid. If pure water is used to dilute this to the proper concentration for battery use, the percentage of the impurity will be proportionately reduced. It is desirable that water of a high degree of purity be used, and no general statement as to the permissible use of natural water can be made for the reason that its purity varies from place to place and from one time of the year to another.

The table on the purity of sulphuric acid and solutions for battery use, has been taken from a recent book on storage batteries.* It is believed that this table is consistent with the results of this investigation and represents acid that can be readily procured. It may be desirable, however, to limit the amount of copper to a smaller percentage in view of the large local action that it produces when present together with certain other impurities.

The term "trace" is often used, but ill-defined. In general this term in these specifications should be regarded as meaning less than 0.001 per cent. Any standard specification of this character should include also a statement of the tests to be employed.

Our experiments have shown that there are other impurities, in addition to those included in the table, which produce effects in the storage battery. However, they are rarely present in sulphuric acid. It does not seem necessary to name them all, as a statement can be added calling attention to the fact that other impurities are absent.

The limits for impurities given in the table are presented for discussion, and it is hoped that they may serve as a basis for specifications that will receive general recognition.—"Power," March 31, 1925.

UNDERGROUND RADIO.

By S. R. Winters.

Recent tests carried on with the underground antenna system of transmission have brought to light some interesting facts bearing on the present theories relative to the propagation of radio waves. Great success has been achieved with Dr. Roger's system, the signals having been heard 1000 miles away.

With a broadcasting antenna system buried four feet in the ground, and with an output of a little less than two ampères of current, Dr. J. Harris Rogers, of Hyattsville, Md., has accomplished the remarkable achievement of radiating electromagnetic waves of sufficient strength to be heard with good audibility at a distance of approximately 1000 miles. In other words, he reversed the common practice of elevating the transmitting antenna to a height of 400 to 600 feet, and with seeming mockery at things conventional submerged the electric-radiating system under four feet of soil.

THE ANTENNA.

This underground antenna was only 100 feet long, consisting of ¾-inch copper tubing, encased in the center of a series of 18-inch joints of terra cotta pipe. After this, four-foot ditches were excavated and the terra cotta pipe, with the copper tubing, placed therein, the openings in the earth were completely filled up. One underground antenna extends in a northerly direction and the other points southward, thus affording opportunity for a study of the directional characteristics of radio signals propagated through the earth.

When the Rogers Radio Research Laboratory, with the call letters 3XR, issued the general call, CQ, the response was immediate and gratifying with respect to the range. Brass pounders—or radio amateurs, to speak with more dignity—by means of postal cards, acknowledged reception at 27 points, located in a dozen states. The geographical locations of the amateurs thus reporting are widely distributed—ranging from Maine to Florida, and with such intermediate states as Massachusetts, New York, Connecticut, Ohio,

* "Storage Batteries," by Vinal, page 120 (1924).

Pennsylvania, Georgia and North Carolina. Offside the directional ranges of true north and south, D. Marshall, operator of Station 9BRG, located at Aurora, Ill., reported that he received 8XR with exceptional strength and absence of fading.

E. Davis, an amateur of Cocoanut Grove, a suburb of Miami, Fla., acknowledged reception, indicating that at 4 o'clock in the afternoon the signals were "loud." The distance between this point and Hyattsville, Md., is approximately 1000 miles. This feat of transmission and reception appears all the more phenomenal when we are told that only 1.8 amperes were put into the antenna and the transmission occurred during daylight. Of the 27 amateur stations acknowledging reception of the signals, 16 specified the audibility as "very loud." Absence of fading or swinging was conspicuously evident in the reception reports.

THE TRANSMITTER.

The transmitting equipment employed in these remarkably successful tests is contained in a rear room of the Rogers Radio Research Laboratory. The well-known Hartley circuit is used. In conducting these novel transmission experiments, two 50-watt vacuum tubes were used. The battery quarters is apart from the transmitting compartment proper, the former occupying a small second-story room. There are available 500 individual storage battery cells, capable of impressing 1000 volts on the plates of the transmitting tubes. The wave-length used during these tests was 185 meters.

PAST EXPERIMENTS.

Connection of the transmitting equipment proper with the buried antenna was effected in a simple way, namely, by the extension of an insulated wire or copper tube from the laboratory through the floor of the building to the underground copper tubing. Preliminary underground transmission tests, conducted by Dr. Rogers a number of months ago, involved three different arrangements of the transmitting apparatus with respect to the conducting medium. In one instance, a single conduit 100 feet in length was used, the transmitter being grounded. In another case, 100 feet of conductor was employed at each end of an ungrounded transmitter. The third arrangement consisted in the placement of 100 feet of conduit at each end of the transmitting station, with the transmitter connected to the ground in the usual way for operating transmitting and receiving equipment.

DIRECTIONAL CHARACTERISTICS.

The peculiar directional properties common to a coil or loop of wire when used for receiving radio signals are accepted knowledge. Buried antennae for transmitting purposes likewise demonstrate pronounced directional characteristics. Not unlike the radio beam system the energy radiated is concentrated in one direction and its force is not dissipated as is true when electromagnetic waves are propagated in all directions. This, in part, probably accounts for the remarkable achievement of Dr. Rogers in radiating electric energy over great distances with the consumption of relatively low power. The Rogers Radio Research Laboratory is now engaged in laying terra cotta pipe for the placing of underground antennae pointing east and west, thus having facilities for radiating electric energy to all points of the compass. The installation of two 250-watt transmitting vacuum tubes will mean an appreciable increase in the output of power during subsequent transmission tests.

The results attending the recent tests justify, Dr. Rogers thinks, the following prediction: "I believe the greatest development of 1925 will be trans-

mission and reception by buried antennae. By the use of such, fading will be eliminated, signal strength will be the same during the 24 hours, the difficulties of 'static' reduced, and, owing to the marked directivity of this form of antenna, less power will be required to cover great distances."

THE EARTH AS A CONDUCTOR.

That the earth acts as a conductor of electromagnetic waves is a theory long ago advanced by Dr. Rogers. He practically demonstrated this, then a revolutionary contention, during the World War. His successful efforts in intercepting and amplifying radio signals emanating from European stations by means of underground antennae are now a matter of history. Recent underground transmission tests further fortify the theory that the earth is a conducting medium for radio waves.

Dr. Rogers, in an interview with the writer, expressed the belief that many of the phenomena experienced in radio broadcasting and reception may be explained in the light of the earth as a conductor. For instance, there are so-called "dead spots" between Baltimore and Hyattsville, which means that it is practically impossible to intercept signals from Baltimore. The presence of vast iron mines may be responsible for this. The fading or swinging of signals is another phenomenon that may be due to the hypothesis that radio waves travel through the earth. For instance, KDKA of East Pittsburgh, Pa., is widely known as radiating signals that frequently fade. The presence of mountains in that section containing an abundance of ore may explain this phenomenon, the minerals absorbing the radio waves.

"Electric waves propagated through the earth spread out perpendicularly to the surface of the earth," explains Dr. Rogers, "while waves propagated from elevated antennae travel diametrically opposite to this. One-half of the energy from elevated antennae actuates receivers over distances around the curvature of the earth. The other half of energy, which is dissipated by elevated antennae, is never bent around or reflected around by the Heaviside mirror. Buried antennae are very effective, even when using relatively lower power, because all of the energy is transmitted to the earth and thus effectively utilized."

Furthermore, as demonstrated by recent tests, Dr. Rogers believes that conditions in effect at the transmitting station influence fading. "The electrostatic lines of force do not, at all times," he explains, "embrace a uniform area, but this field of energy is constantly expanding and contracting. The result is that the strength of the electromagnetic waves radiated from elevated antennae varies in proportion to this contraction and expansion.

"This elastic condition in the electrostatic field may be attributed to changes in the space above the earth, such as passing clouds, and to the ionization of the atmosphere. However, when antennae are buried or submerged under the surface of the earth, the electromagnetic waves thus propagated are not subject to the fluctuating conditions prevalent in the hypothetical ether—or, at least, they do not exist to such a marked degree."

The results of these underground transmission tests indicate that radio waves thus propagated are not influenced by the seasonal changes of night and day. In the parlance of the street "it is fair weather all the time" for radio reception when shooting electromagnetic waves through the earth instead of radiating these invisible particles of energy through the ether. That is to say, in the 1000-mile test between Hyattsville and a suburb of Miami, Fla., the signals transmitted during the day and after nightfall were the same with respect to audible strength and their absence of fading at the receiving point.—"Radio News," April, 1925.

A NEW METHOD OF TELEVISION.

By W. G. Walton.

Below Is Given a Description of the Newest Method of Transmitting Photographs By Radio or Wire at Such a Speed as to Enable the Distant Envisioning of Transpiring Events.

Mr. W. G. Walton, in the interest of scientific progress, has kindly given an interview for "Radio News" in which he explains the great difficulties in accomplishing the "Radio Movie," the ultimate object of his research. Both he and Mr. W. S. Stephenson, of the General Radio Company, London, have done a great deal of research work in the matter of the transmission of pictures by radio, and have made some highly interesting discoveries.

WHAT HAS BEEN DONE.

"For a matter of 30 to 40 years attempts to transmit pictures by electrical means have been made, and the advent of the motion picture led to dreams of transmitting pictures at such a speed that a motion picture effect could be produced," Mr. Walton said.

"The light sensitive device has been, and still is, the greatest source of our troubles. Selenium cells have the disadvantage of slow action and lag, while photo-electric cells, though faster, give only very minute currents which need amplifying by many stages of resistance coupled vacuum tube amplifiers. Neither of these devices is a desirable feature of commercial apparatus. The time required by the fastest apparatus is too long. To be an entire success, apparatus must be faster and such that it can be used at a moment's notice without many adjustments, and the reception of a reasonable picture must be a certainty.

"Television or the radio movie," he continued, "is the transmission and reception of pictures by electricity in such rapid succession that a motion picture effect is obtained. Apparatus for this purpose is generally the same as that used in the transmission of photographs, but operating at a much greater speed."

ONE METHOD.

One of the methods is to traverse the picture in lines by optical arrangements and transmitting impulses, the strength of which depends on the intensity of the small sections of these lines as they are shown in succession on a light sensitive device.

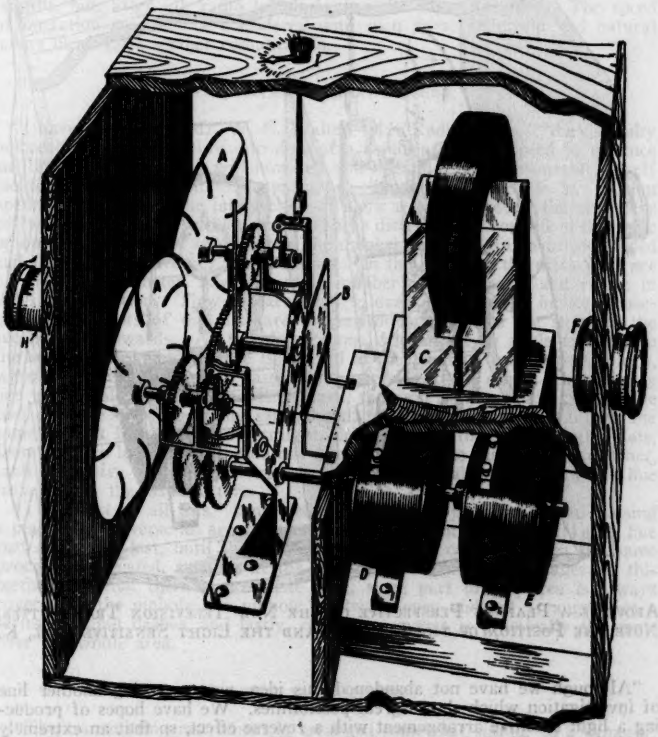
At the receiving end a beam of light varied in intensity by a shutter actuated by the impulses received from the transmitting end is traversed over a screen by an optical arrangement similar to that used at the transmitting end. Everything depends upon the rate at which the light sensitive device can respond and also the light controlled shutter at the receiving end. This refers to schemes using one cell.

MILLIONS OF DOTS.

Before difficulties in the way of television can be appreciated, the number of dots necessary to produce a reasonable picture must be known. Television to be a complete success must have almost as good a definition as the standard motion picture. With a picture of one square foot consisting of a million dots and held a foot away from the eye, an average person will be able to distinguish the dots. Such a picture will give good detail of a town or landscape view.

SPEED.

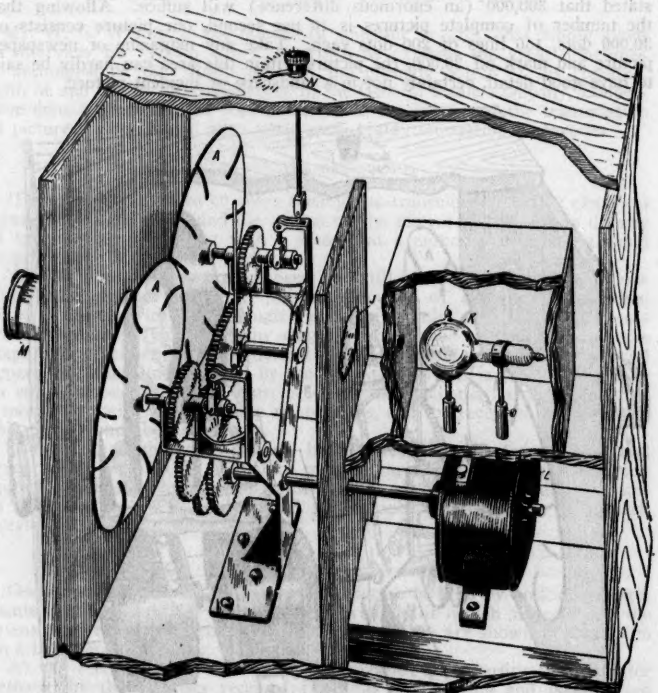
Motion pictures are shown at the rate of 16 per second. Taking this as the rate at which complete pictures must be repeated by television apparatus, our light sensitive device in single cell methods has to respond to 18,000,000 different impulses per second, and so must the light control shutters. This is, of course, putting the problem at its worst. Some investigators have stated that 300,000 (an enormous difference) will suffice. Allowing that the number of complete pictures is 10 per second, our picture consists of 30,000 dots, 150 lines of 200 dots each. Take any magazine or newspaper picture and mark off 30,000, the picture within this area can hardly be said to have good detail, certainly not in a landscape or incident picture.



THE REPRODUCING APPARATUS WHICH RECREATES THE IMAGE TRANSMITTED TO IT BY THE SENDER.

We are striving to produce something as good as the motion picture, and though 18,000,000 per second is high, it is a good ideal to aim at. Light sensitive devices as used up to the present time have not been able to respond to anything like such a speed.

"Mr. W. S. Stephenson and I," Mr. Walton continued, "have done a considerable amount of research work. In an endeavor to discover something much faster, we tried the possibilities of vacuum tubes to see if light would affect a stream of electrons by bending the stream or otherwise producing some action. Results were doubtful, masked by other things such as light from the filaments.



ABOVE IS A PLAN IN PERSPECTIVE OF THE NEW TELEVISION TRANSMITTER. NOTE THE POSITION OF THE LENS, M, AND THE LIGHT SENSITIVE CELL, K.

"Although we have not abandoned this idea, we are trying another line of investigation which shows great possibilities. We have hopes of producing a light sensitive arrangement with a reverse effect, so that an extremely rapid shutter will not be required at the receiving end."

HETERODYNING WAVE-LENGTHS.

Light waves are electromagnetic in nature, differing from radio waves only as regards wave-length, though the difference is great. Our endeavor is to convert light frequencies into radio frequencies by an action similar

to heterodyning (super imposing one wave-length on another) in several steps. The radio frequency thus produced is, after amplification, transmitted direct without modulating a carrier wave. The possibility is now apparent. A picture consisting of light waves is converted into an invisible picture of radio waves which, after amplification and reconversion at the receiving end, produces a visible image on the screen. As just described, the trouble is in sorting out the waves and putting them in their respective positions at the receiving end. But if the picture at the sending end is split into sections, and each section has a frequency of its own, then the rearrangement at the receiving end is only a matter of reversing the operations which took place at the transmitter.

The transmission of the pictures would mean the use of a band of wave-lengths, but, after all, radio telephony has the same difficulty. The speed of operation need not be considered with such an arrangement and natural colors mean little further complication.

THE PROCESS USED AT PRESENT.

"I have explained," Mr. W. G. Walton told "Radio News," "the difficulty in breaking up the picture into dots at a sufficiently high speed to produce an illusion of motion. I will now tell you how Mr. Stephenson and myself tackle the problem with our apparatus. The method used is by causing apertures formed by the intersection of slots arranged around the periphery of two discs to traverse the picture. These discs may be rotated in the same or opposite directions, according to the number and disposition of slots used and the relative speeds of the two discs. In the sketches, the discs (A) are of the same diameter, have the same number of slots each, and rotate in the same direction. They are arranged to overlap about 1½ inches, consequently the slots of one disc are moving downward and the slots of the second disc upwards. As the slots of one disc are at an angle to those in the second, a minute aperture is formed at the point of intersection, which, when the discs are rotating, passes from one side to the other. Immediately one pair of slots has become disengaged, the next pair engage. Should the two discs be rotating at the same speed, all the apertures will follow the same path, a line, curved or straight, depending on the shape of the slots, from right to left. Now should one disc rotate a little faster than the other, each successive aperture will traverse a line a little above or below the line traversed by the last aperture.

"The effect of all this," continued Mr. Walton, "is equivalent to causing a pinhole to traverse an area in successive lines from right to left, each line just above the last, until the whole area has been covered, when the same process is repeated, starting at the bottom. The great advantages of this method are that there is no waste time, some part of the area is always covered by the pinhole, the pinhole is always open and not arranged for a series of rapid flashes, and lastly, speed of traverse is practically the same over the whole area.

THE TRANSMITTER.

"The transmitting instrument is arranged somewhat similar to a camera," explained Mr. Walton. "A lens (M) (on the sketch) throws an inverted image about one inch square in a plane parallel to and just between the overlapping discs (A, A). The slots in the discs are about .002 of an inch wide, therefore the pinhole formed by intersecting slots is about the same diameter. As I explained, the pinhole traverses the whole of the inverted image, allowing a small area of light at a time to pass through. This light

is then focussed by a lens marked (J) onto a light sensitive cell (K). The varying electric currents from the cell and a speed control current are then transmitted by radio or other means to the receiving station.

THE RECEIVING STATION.

"It is obvious that similar sets of discs must be used both at the transmitting and receiving stations," Mr. Walton continued. "At the receiving station a source of intense white light such as an electric arc is placed behind the lens marked (F), which concentrates the beam on a light control shutter (C), shown diagrammatically as a four-string Einthoven galvanometer. The light having been controlled by the shutter is then thrown on a white diffusing screen (B). An area of this screen throws light through the aperture formed by the slots of the discs onto the lens (H), which focusses the light in a spot on an ordinary projection screen. The received electric current, *i. e.*, current corresponding to the current from the light sensitive cell at the transmitting end, and the speed control current, are applied, the first to the light control shutter (C), and the second to maintain synchronism between the transmitting and receiving machines.

"It is possible when the two machines have just been started and synchronized that the spot of light shown on the screen is not in its correct position, in which case by means of the 'advance' or 'retard' control (I) can be rectified even while the machine is operating at full speed.

"I have mentioned the spot of light shown on the screen, but actually this spot would be moving at such a speed that a continuous image would be seen much the same as the motion picture image.

SOME REMARKABLE FIGURES.

"This is the type of machine which was evolved after careful consideration of many ways of accomplishing the results. Quite the most important point is the amount of light passing through the shutters onto the light sensitive cell, and at the receiving end onto the screen. With the above method the focussing of the beam of light at the receiving end into a narrow pencil of light is unnecessary. The amount of definition available is purely a question of the width of the slots and the gearing of the discs. We use slots .002 inch wide, and one disc does 1000 revolutions while the other does 999, consequently our picture consists of 1000 lines with 50 per cent overlap between lines. The number of dots in each line—if such a term may be used—depends on the speed of the light sensitive cell and the light control shutter. Should the cell be slow, it will respond only to an average effect beyond its speed of response; in other words, the reproduction would be very blurred. These remarks apply also to the light control shutter.

THREE-COLOR METHOD.

"Another interesting arrangement we have brought out is for natural color reproductions. This is a three-color method similar to that used in photography. At the transmitting end there are three light sensitive cells, each of which respond only to one color and at the receiving end there are three light control shutters, each actuated by currents from one light sensitive cell only. The shutters pass light only of one of the three colors which are mixed and then shown on the screen. The shutter in this case could be a three-string Einthoven, each string independently operated.

"I hope," concluded Mr. Walton, "that what I have told you will be of use to other experimenters along the same lines."—"Radio News," April, 1925.

ELECTRIC ARC WELDING APPLIED TO SHIP REPAIRING.

By A. G. Bissell.*

In the field of steel ship repairing, electric arc welding has many applications. The ease with which two pieces of steel may be united by this process makes it indispensable in repair yards. The "Putting on Tool," the ship fitter's joke of yesterday, is a reality in the electric arc welding process of today. There is probably no shop in the steel ship repairing yard but has use at some time or other for the services of the arc welder. By the use of this process repairs are accomplished that in the past could not have been attempted and within time limits that are of great assistance to shipowners.

One of the most common repair jobs on which arc welding is used is in the installation of patch plates or in "blanking off" holes in bulkheads, deck and shell plates. To do these jobs successfully requires that the welding operator exercise considerable care to avoid failure due to the shrinkage of the parts involved. When the proper procedure is followed the shrinkage is reduced to a minimum and a sound strong job results. This method has been used to insert a patch in a bottom shell plate to repair damage done by a ship riding its anchor at low tide. Patches in the gun shields of the secondary battery of several dreadnaughts were successfully installed by electric arc welding and withstood the several tests that were applied to them.

Arc welding is admirably adapted to underwater body repairs. Where the corrosive action of the sea water assisted by the electrolytic action

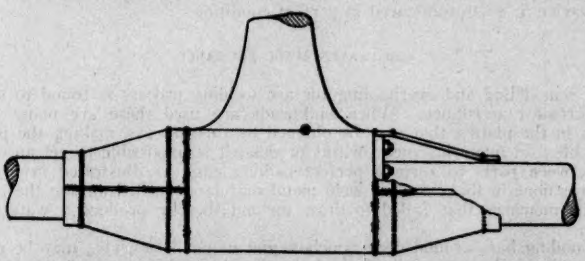


Fig. 1.—Method of Securing Fairwaters to Propeller Shaft Bearing.

between the bronze propellers and the steel stern frame and rudder have corroded these parts, the electric arc process of welding may be used to quickly and efficiently replace the metal removed.

Where the rudders are built of plates on frames, the rivets and seams become quite badly rusted and corroded and the rudders become filled with water. The rudder is drained and using the arc the leaking rivets and seams are sealed and the rudder made watertight.

FAIRWATERS WELDED TO BEARING CASTINGS.

The fairwaters on the external bearings of propeller shafts usually fail to last from one docking period to the next. Due to the vibration of the rotating shaft the bolts are loosened and the excessive corrosion soon causes them to become detached. In many cases they are loose on the shaft or

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missing entirely when the ship is dry docked. It has been found very satisfactory to secure the fairwaters to the bearing castings by the electric arc welding process. They are constructed in the same manner as for bolting except that no bolt holes are punched. The welding in the assembly is done in the shop. In attaching, the bolt holes in the castings are welded solid and the fairwater fitted in place and secured by tack welds as illustrated in Fig. 1. The cut away view shows how the three sections of the pieces are welded together in the shop.

Seams on underwater bodies where calking fails to give the desired results are easily sealed by depositing a bead of arc weld metal along the calking edge. Fig. 2 shows an arc welder repairing a steel plate on the underwater body of a tug.

There are many occasions when repairs are being made as in replacing a stern frame and rudder post that the plates cannot be made to draw up perfectly. These seams may be sealed and made perfectly watertight by depositing arc weld metal along them. Irregularities in these stern frames may be built up to the desired height at very little cost, eliminating the use of liners.

On twin-screw ships having propeller guards these may be made either of structural steel or of 3-inch wrought iron pipe having all joints and connections to the steel plates arc welded.

A light steel vessel in a collision broke its stem about 6 feet below the deck line. Instead of removing the entire stem, or making a riveted splice, a new piece was made to fit in place of the upper end and was arc welded to the old, a satisfactory job being obtained. When inspected after a year of service, it was pronounced in perfect condition.

OLD PLATES MADE REUSABLE.

In remodeling and overhauling the arc welding process is found to be of the greatest assistance. When bulkheads are used there are many rivet holes in the plating that may be plugged by this process, making the plates reusable. In many instances in this process, it is impossible to get an exact fit between parts to form a perfect calking edge as illustrated in Fig. 3. As was done in this case, arc weld metal may be deposited uniting the edges of the members that failed to draw up and thereby produce a watertight joint.

Bounding bars around deck winches, gun mount bases, etc., may be made by bending a flat bar to the desired shape and attaching it to the deck with a light fillet weld. This eliminates the use of angles which cost more to shape, require that the decks be drilled and that the entire job be calked. The installation of waterway bars is greatly simplified by the use of arc welding. In the same way that bounding bars are installed waterway bars may be attached to a steel deck with a fillet weld on each side of the bar.

FITTINGS ATTACHED TO DECKS AND BULKHEADS BY WELDING.

Fittings such as pad eyes and deck clips, for securing miscellaneous gear, may be easily and quickly attached to decks and bulkheads. When fittings are to be secured to watertight bulkheads or other plating too thin to be successfully tapped, a pad of heavier plate may be welded to the thinner material to receive these screws without puncturing the bulkhead. The installation of grab irons and clips for securing steel ladders may be accomplished by arc welding with much less labor than by riveting.

Quite often, due to the abrasion caused by the anchor chains passing in and out, the cast iron hawse pipes on ships become badly grooved and cut. These cuts may be successfully filled with steel with or without studding.

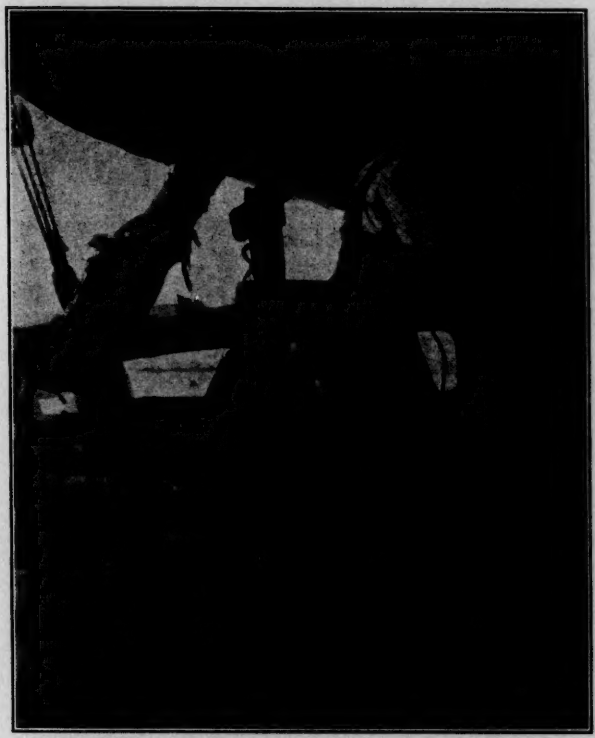


FIG. 2.—ARC WELDING SHELL PLATING ON TUG.

FIG. 3.—ARC WELDING USED IN PLACE OF CALKING.

If the grooves are deep it probably is better to drill and tap holes throughout the cut on about 3-inch centers to receive ½-inch bolts. These bolts are cut off to a length just below the level of the finished job. The weld metal is deposited around and over these studs until the desired elevation is obtained, care being taken that the work is kept as cool as possible. If the hawse pipe has been cracked, the procedure is identical except the crack is completely chipped out and studs installed in the bevelled section. These methods of repair have been used with very successful results on many ships.

NEW METHOD OF FASTENING ICE GUARDS.

A rather ingenious use was made of arc welding in securing timbers to the shell of a ship in connection with the installation of ice guards. The customary procedure would have been to bolt these timbers to the shell. The bounding angle would have been riveted to the shell. In bolting through

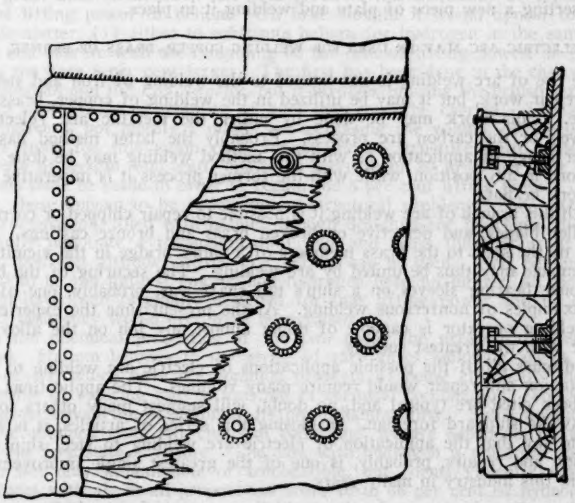


FIG. 4.—METHOD OF INSTALLING ICE GUARDS ON BOW OF TUG.

the shell, there is difficulty in keeping the shell from leaking around the bolts. Two-inch round mild steel stock cut in 1-inch lengths, drilled and tapped to receive a ½-inch bolt were attached by a fillet weld to the shell of the ship as shown in Fig. 4. The bounding angles were welded at the heel and toe. The timbers were counterbored to fit over the lugs. One-half-inch bolts passed through a washer and the timber engaged the threads in the disk securing the timber to the shell. The bolt head and washer fitted into a recess in the outside of the timber which was sealed with a wooden plug and white lead. The timbered surface was entirely covered with sheet steel held in place with spikes.

Ovens of galley ranges that have become badly rusted and burned may be quickly and cheaply replaced by arc welding. The old oven is removed

by cutting it free from the range frame just inside the door. The new sheet metal oven is slipped in place and a light bead of weld metal secures it in place. Straps of light metal welded to the oven and the range frame secure the inside ends in place.

There are many instances in the repair of awning, guard rail and life line stanchions on which arc welding may be used. In most cases the repairs may be made without removing the stanchions from the ship.

When tank tops, bulkheads and shell plating leak from seams opening or damage to the steel plates, it is a simple matter to put a calking weld along the faulty seams and ring the rivets by arc welding, or, if necessary, a plate may be placed over a damaged or corroded area and, with a fillet weld around the edges, secured to the original plate, making a watertight job.

The combings of watertight hatches and doors become notched and otherwise damaged in service so they fail to make a tight fit with the gasket on the hatch cover or door when they are closed. These low and damaged sections may be repaired by building up the surface with arc weld metal or by inserting a new piece of plate and welding it in place.

ELECTRIC ARC MAY BE USED FOR WELDING COPPER, BRASS OR BRONZE.

The use of arc welding is not limited to the welding of iron and steel in ship repair work, but it may be utilized in the welding of copper, brass and bronze. This work may be done by either the metallic arc (electrode positive) or the carbon arc process. Probably the latter method has the greater range of application as with this method welding may be done with the work in any position, while with the former process it is imperative that the work be flat.

With this branch of arc welding it is possible to repair chipped or corroded propeller blades, and defective or broken brass and bronze castings. The joints of the steel to the brass members of a ship's bridge in the vicinity of the binnacle may thus be united by arc welding. The securing of the brass or bronze bearing sleeves on a ship's tail shaft was, probably, one of the first examples of nonferrous welding. At the present time the experienced arc welding operator is capable of doing almost any job on the alloys of copper with the greatest success.

To discuss all of the possible applications of electric arc welding to ship construction and repair would require many volumes. The applications that have been cited are typical and, no doubt, will suggest many others to the wide-awake shipyard foreman. In closing this series of articles, it is sufficient to say that the application of electric arc welding to steel ship construction and repairs, probably, is one of the greatest single improvements made in this industry in many years.

HELIUM FOR AERONAUTICAL USE.

A Discussion of Its Development and Advantages for Lighter-than-Air Ships.

By S. C. Lind, '02,

Chief Chemist, U. S. Bureau of Mines, Washington, D. C.

The headline writer of a western daily recently compressed the description of the two properties of helium which make it suitable for aeronautical use into the following irreducible minimum: "Helium will go up but will not blow up." When the truth of this statement is fully appreciated there remains but little to be said except as to some of the details of its utility,

such as the following: (1) Can it be found and secured in sufficient quantity; (2) can it be obtained pure at an allowable cost; (3) is its lifting power sufficient; (4) how long will its supply last?

Assuming the general utility of lighter-than-air craft, the value of helium as a lifting gas then becomes merely a matter of comparison with hydrogen, since these are the only two gases sufficiently light to be considered for major aeronautical use.

Physically, both helium and hydrogen are colorless, odorless and much lighter than air. One thousand cubic feet of air at atmospheric pressure and 200 degrees C. weigh 76 pounds. The same volume of hydrogen weighs five pounds and of helium ten pounds (in round numbers). The lifting power of a light gas in a heavier one is the difference in weight of equal volumes of the two gases. Therefore, the lifting power in air of 1000 cubic feet of *hydrogen is 71 pounds* and of *helium 68 pounds*, or 92 per cent of that of hydrogen.

A great deal of attention has been given to this deficiency of 8 per cent in the lifting power of helium. On first thought it would appear to be a simple matter, (1) either to substitute helium for hydrogen in the same gas bags and operate with the remaining 92 per cent of lifting power, or (2) to make the bags 8 per cent larger. The first has been done in the case of the *Shenandoah* and the *Los Angeles*, but it involves limiting the cruising radius, owing to the reduced quantity of fuel that could be carried. The second alternative is not merely a matter of increasing the volume of the bag by 8 per cent, for this again calls for additional structure with consequent increase of weight, etc., until finally an increase of 20 to 30 per cent in the volume must be made in order to regain the 8 per cent lifting power. However, these appear to be rather minor structural problems. The fact that the *Shenandoah*, filled with helium, though designed for hydrogen, did successfully negotiate a transcontinental tour and cross the Sierras at more than 7000 feet altitude, proves that helium can be used. Had helium happened to be the lightest gas, or had hydrogen been no lighter, all air craft would have been originally designed for that lifting power and no claims of its deficiency would ever have been raised.

In the chemical properties of the two gases the greatest difference is found. Helium belongs to the series of rare gases including argon, neon, and others, which have the common property of being chemically inert or incapable of entering into or existing in chemical combination. Herein lies the great advantage of helium,—its non-inflammability. Since helium cannot be obtained from any chemical compound, we are dependent on finding it in the free state in nature. The case with hydrogen is quite the opposite. It is not only inflammable or combustible, but forms violently explosive mixtures with air in all proportions from 10 to 66 per cent of hydrogen by volume. Although it is not available in the free state in nature, it is a constituent of many of our commonest chemical compounds, such as water, acids, fats, oils and all hydrocarbons and carbohydrates, and can be prepared chemically by a large variety of processes and is hence universally available. The one supreme disadvantage of hydrogen which outweighs all of the advantages it may have, its combustibility, has either caused or contributed to the greatest airship disasters of the past. Furthermore, owing to this same property, hydrogen cannot be readily purified after it has become contaminated with air in use, and must be discarded. The annual replacement factor in the bags would be normally about fifteen-fold, which makes its use actually more expensive than helium at its present cost,—assuming, of course, that water condensers will be used on the exhaust gases, so as to maintain weight and avoid loss of helium by valving.

The principal events leading up to the present status of the use of helium have been the following:

Discovery in the sun by its spectral lines (Lockyer and Franklind, eclipse of 1868).

Discovery on the earth in radio-active minerals (Ramsey, 1895). Quantities from this source were very limited—a few cubic feet.

Discovery in quantity (1 to 2 per cent by volume) in the natural gases of Kansas (Cady and McFarland, 1905).

Conception of its possibilities as a military aeronautic gas (by the Allies in 1917, during the World War).

Immediately following the appreciation of the possible value of helium in lighter-than-air craft, a survey of our helium resources was undertaken by the Bureau of Mines and the Geological Survey. A suitable source was discovered in the natural gas from the Petrolia field in Northern Texas, which is used as city gas supply of Dallas and Fort Worth.

With the co-operation of the Army, the Navy, the Bureau of Mines, and commercial companies, an experimental plant was established at Fort Worth. Three methods of recovery were attempted, all of which were dependent on separation of helium as a gas from the other constituents, hydrocarbons (chiefly methane) and nitrogen, after their liquefaction by low temperature methods. Of the three methods, only that of the Linde Air Products Company was successful. The process which this company had employed for the separation of oxygen from air was so modified as to effect the separation of helium from natural gas. A full scale plant of six units, capable of processing 5,000,000 cubic feet of raw gas daily, was erected at Fort Worth. This plant, now known as U. S. Helium Production Plant No. 1, is operated by the Linde Company under the supervision of the Navy, at the joint expense of the Army and Navy. During the past year some six to nine million cubic feet of pure helium (95 to 98 per cent) have been produced for the use of the Navy at Lakehurst, N. J., and of the Army at Scott Field, Belleville, Ill.

A year ago the cost of production was about $100 per thousand cubic feet of helium. During the past year great progress has been made in improving the process, with consequent reduction in cost. The present cost of production is about $35 to $40 per thousand, with an anticipated reduction to $15 to $20 during the coming year. This will be the manufacturing cost f. o. b. cars at Fort Worth, without allowance for interest on the investment.

In 1919 a Helium Board was formed, comprising representatives of the Army, Navy and Interior Departments. This Board found that new data would be required regarding the properties of the gaseous and liquid mixtures encountered in the separation of helium from natural gas by the refrigerative method, before efficient methods could be devised and plants intelligently designed for the extraction of helium. The Cryogenic Laboratory was established in the Bureau of Mines, at Washington, in 1921, to carry on the researches necessary to secure these data. It was dedicated by Madame Curie in 1921 and put in charge of Dr. R. B. Moore, who had been a leader in the helium work from its inception. The fundamental principles underlying all the improvements in process which have just been referred to resulted from the data obtained in this laboratory, affording a good demonstration of the value of systematic research. It is still conducted with the co-operation of the Army and Navy and at their expense.

In 1921, Dr. H. F. Bain, Director of the Bureau of Mines, appointed a Board of Consulting Engineers to render a report on one of the three original processes which had not proved successful. The Board, consisting of M. H. Roberts, chairman; R. C. Tolman, W. L. DeBaufre, and Edgar Buckingham, became directly interested in helium production and devised a new process for government use, which has proved successful on a semi-commercial scale. The first unit is now being installed at Fort Worth on a full commercial scale. This process should also be capable of producing very cheap helium—$15 or less per thousand cubic feet.

It is now thoroughly appreciated in this country that lighter-than-air craft cannot be safely operated without helium. The Army and Navy have abandoned the use of hydrogen entirely. Now that the actual success of helium flying has been repeatedly demonstrated by the Navy and Army of the United States, there remain but two primary questions with reference to helium—those of supply and cost. It is admitted by those commercially interested in dirigibles that helium at a cost of $25 a thousand would be acceptable. We have just seen that it can be obtained for this now and that the price is likely to be still further lowered, so that it will actually be cheaper than hydrogen at any cost, even leaving out of account the danger attendant to the use of hydrogen, which involves higher insurance rates and lack of confidence on the part of the investor and of the public as prospective passengers. It is then quite clear that with the use of helium a demonstrated fact, and with its cost reduced to a satisfactory basis, its future will depend alone on whether it can be secured in adequate quantities. The present situation is that the United States possesses the only commercial quantities of helium known. This monopoly has stimulated the military interest in helium, but it is not safe to rely on our retaining this monopoly indefinitely in the future. Other countries may discover helium, or ours may become exhausted, or the two may coincide most unfortunately.

Our helium resources consist of certain natural gases occurring in several western states, all of which have been discovered incidental to drilling for oil or gas. Their helium content varies from a few hundredths of one per cent up to about two per cent by volume. Under present conditions 0.5 per cent of helium is considered the lowest limit, the extraction of which would be commercially feasible, but with future improvements of process, we may expect to go considerably below this limit; such has been the history of all processes of mineral recovery. We have large quantities of helium in gases above 0.5 per cent, or even above one per cent, but unfortunately it is being wasted at an alarming rate.

It is estimated that the present loss by failure to recover is several hundred million cubic feet of helium a year, or enough to fill a whole fleet of Zeppelins. These wastes of helium could be stopped in two ways: (1) By legislation. The only proposal in this direction has been for the United States Government to acquire helium reserves for military use. One such reserve was set aside on public land in Utah in March, 1924. No other discovery of helium has been made on public lands and hence additional reserves would have to be purchased or leased. Legislation is now before Congress providing for a conservation fund, which, if enacted, would enable the purchase or lease of enough reserves for the Army and Navy use for a long period of years. Our present knowledge of helium resources indicates that after such reserves have been set aside there would be left a large and sufficient quantity of helium for commercial use.

(2) The second method of conserving helium is for the owner himself to hold it for its future value, or for a commercial company to establish its own reserves. There is nothing to prevent such action now, but the use of helium has not yet reached a stage regarded as warranting it.

The situation is unique in some of its aspects. The discovery of a helium-bearing gas well is too rare to justify prospecting for helium alone. The discovery must come incidental to the search for gas or oil, but in this way the helium is subjected to waste or total loss. Some time it will be regarded as a valuable by-product, but possibly not until depletion shall have progressed too far. Today we have a world monopoly. If we waste this priceless resource before or during its development some other country with the future monopoly may enjoy the benefit of our development and demonstration work, to our great industrial and military disadvantage. When the conservation of helium for military use has been provided for the field data

which are now held confidential can then be opened up for the benefit of the owners of helium-bearing gas, as well as for the prospective commercial purchaser or user.

So far the only other discovery of helium of any importance is that in Canada of a rather limited quantity of natural gas bearing 0.3 per cent of helium. Several thousand cubic feet of helium were extracted from this gas in an experimental plant by Professor J. C. McLennan and Mr. J. Patterson. It is more than striking that Canada with these hitherto limited resources, already possesses the necessary legislation for the future conservation and utilization of helium; while this country, so richly endowed with natural resources of helium, has as yet taken no steps for their proper conservation or protection.

One of the latest developments in the use of helium is the erection by the Bureau of Mines of a repurification plant for the Navy at Lakehurst, N. J. The plant was designed to repurify helium from the gas bags which had become contaminated with air by diffusion. It has a capacity of about 480,000 cubic feet of gas per day and can therefore repurify all of the gas from the *Shenandoah* or *Los Angeles* in a matter of five days. The purity attained is about 98 per cent. The loss of helium in the operation is not more than one per cent and the cost is less than $1.00 per thousand cubic feet of helium, or a small fraction of its original cost of production. A high state of purity is very important from the standpoint of its lifting power, since the loss of each per cent of purity by the introduction of air entails a loss of lifting power of about 4 per cent. It will now be both simple and economical to keep the gas at high average purity by frequent retreatment, which would not be possible in the case of hydrogen, as already pointed out, owing to the explosibility of the mixtures that would result upon compression in the refrigeration process.—"The Tech Engineering News," March, 1925.

EDITOR'S NOTE: This article is printed by permission of the Director of the Bureau of Mines, Washington, D. C.

AIRCRAFT ENGINE PROGRESS.

LIEUT.-COMDR. E. E. WILSON, U. S. NAVY,

Head of Power Plant Section, Bureau of Aeronautics.

In the beginning, man's ability to fly depended upon his ability to build a suitable engine. Since the beginning, continued progress in flying has hinged about continued progress in engines. To the everlasting credit of American engine builders, it must be said that they have not only met every requirement but have anticipated the demands of the designers in every way. As a result, we now have in this country dependable, proved engines in every power from 70 horsepower to 800 horsepower, a truly remarkable selection from which to choose.

This fact is apparent from the chart, Fig. 1, in which are plotted curves of our proven engines. This chart includes only those engines which have been or are in production and gives a conservative power rating based on normal compression ratios. It does not include experimental or semi-experimental engines which will be covered later in this paper.

From the chart it will be seen that there are two proven engines in the 200 horsepower field. These are the Wright Model "E" and the Wright Model "J." The former is the old Hispano-Suiza expanded and developed to the point where it is without exception the most durable engine in the world. It was this engine that completed successfully a 300-hour endurance

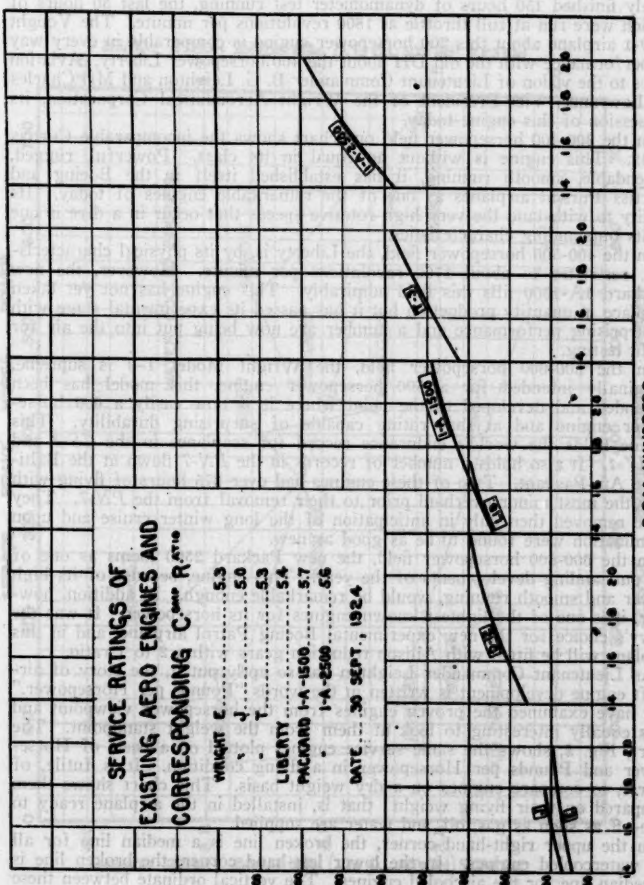

SERVICE RATINGS OF
EXISTING AERO ENGINES AND
CORRESPONDING C.mep RATIO
WRIGHT E.....5.3
" J.....5.0
" T.....5.3
LIBERTY.....5.4
PACKARD 1-A-1500.....5.7
" 1-A-2500.....5.6
DATE.....30 SEPT., 1924
BRAKE HORSEPOWER - SERVICE RATINGS
R.P.M. HUNDREDS
E-4
J-4
1A-1500
T-3
1A-2500

FIG. 1.

run at the Aeronautical Engine Laboratory. The Model "J," now being built as the J-4, is the old Lawrance "J" engine improved and developed to the point where it has now taken its place as a standard engine in the Navy for training, observation, and fighting airplanes. One of these engines has lately finished 150 hours of dynamometer test running, the last 50 hours of which were run at full throttle at 1800 revolutions per minute. The Vought UO-1 airplane about this 200 horsepower engine is comparable in every way in performance with the old DH about the 400 horsepower Liberty. Aviation owes to the vision of Lieutenant Commander B. G. Leighton and Mr. Charles L. Lawrance, Vice-President of the Wright Aeronautical Corporation, its possession of this engine today.

In the 300-400 horsepower field our chart shows the incomparable Curtiss D-12. This engine is without an equal in its class. Powerful, rugged, dependable, smooth running, it has established itself in the Boeing and Curtiss Pursuit airplanes as one of the remarkable engines of today. Its ability to withstand the very high rotative speeds that occur in a dive is one of its outstanding characteristics.

In the 400-500 horsepower field, the Liberty is, by its physical characteristics, restricted to about 1700 revolutions per minute. However, the new Packard 1A-1500 fills this field admirably. This engine has not yet taken its place in quantity production but it has passed its experimental stage with a surprising performance and a number are now being put into the air for flight testing.

In the 500-600 horsepower field, the Wright Model T-3 is supreme. Originally intended for a 500 horsepower engine, this model has been expanded and developed to the point where it is now easily a 600 horsepower engine and at that rating capable of surprising durability. This engine holds the world's endurance record for seaplanes in the *CS-2* and *SDW-1*. It also holds a number of records in the *PN-7* flown at the Baltimore Air Pageant. Two of these engines had over 275 hours of flying with only the most minor overhaul prior to their removal from the *PN-7*. They were removed then only in anticipation of the long winter cruise and upon examination were found to be as good as new.

In the 600-800 horsepower field, the new Packard 2500 looms as one of the outstanding developments of the year. This engine, because of its high power and smooth running, would be remarkable enough. In addition, however, it is one of the lightest known engines for its horsepower. It was the Navy's choice for the new experimental Boeing Patrol airplane, and in this airplane will be fitted with Allison reduction gears with a 2 to 1 ratio.

As Lieutenant Commander Leighton has so aptly put it, the story of aircraft engine development is written in the words "Pounds per Horsepower." We have examined the proven engines from the horsepower viewpoint and it is equally interesting to look at them from the weight standpoint. The chart, Fig. 2, shows the same service engines plotted on a basis of Horsepower and Pounds per Horsepower in a flying condition. It is futile, of course, to compare engines on a dry weight basis. This chart shows them compared on their flying weight; that is, installed in the airplane ready to take-off as soon as gas, oil, and water are supplied.

In the upper right-hand corner, the broken line is a median line for all the watercooled engines. In the lower left-hand corner, the broken line is a median line for the aircooled engines. The vertical ordinate between these lines is about .7 pound per horsepower, which is a good average weight for the cooling system. In the watercooled field, we note that the Curtiss D-12 lies exactly on the median line; the Wright E-4 and T-3 engines are above this line. It must be remembered, in justice to these two engines, that considerable weight has been added to them because of over-speed and high power running. The Packard 1A-1500 and the Packard 1A-2500 are found close to the median line in a position which very unique construction places

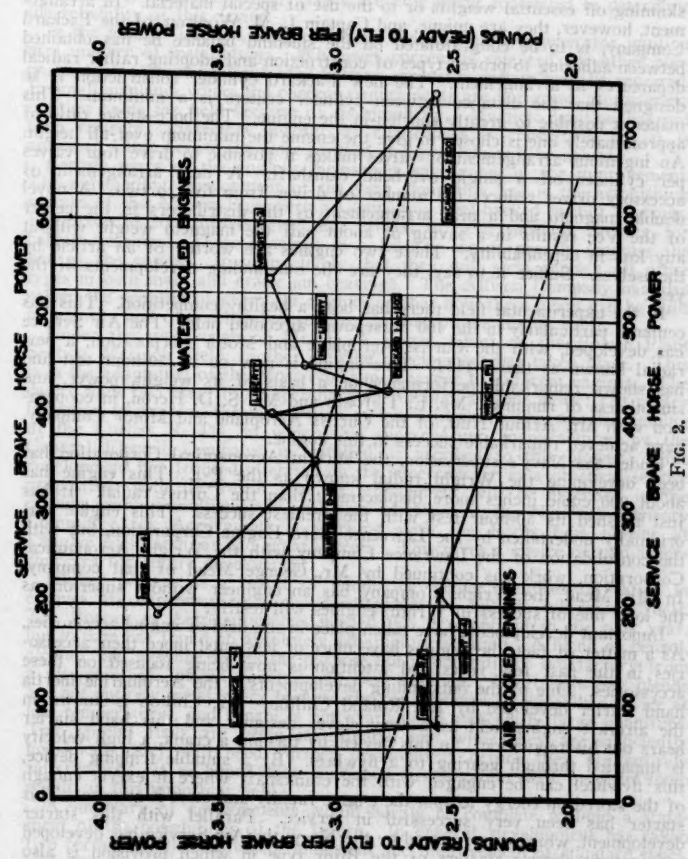

POUNDS (READY TO FLY) PER BRAKE HORSE POWER
4.0
3.5
3.0
2.5
2.0
SERVICE BRAKE HORSE POWER
0
100
200
300
400
500
600
700
WATER COOLED ENGINES
AIR COOLED ENGINES

FIG. 2.

them. In the aircooled field, the Wright J-4 and the Wright P-1, a 400 horsepower aircooled engine which has just passed its tests, make up the line.

As has been stated, the outstanding development of the year has been the rise of the two Packard engines. The splendid weight-power ratio of these engines is not due in any way to freak construction. Neither is it due to skinning off essential weights or to the use of special material. In arrangement, however, they are unique, and Captain L. M. Woolson, of the Packard Company, is to be congratulated on the splendid balance he has obtained between adhering to proved types of construction and adopting rather radical departures in arrangement. The new Packard cylinder construction is so designed that the distance between cylinder centers is a minimum. This makes it possible to greatly shorten-in the engine. The bore-stroke ratio of approximately one is chosen to give the engine the minimum over-all height. An ingenious arrangement of valves makes it possible to drive four valves per cylinder off a single overhead camshaft. A neat arrangement of accessory drives reduces the number of drives from five to two. A novel double magneto and a neat arrangement of the distributors in the center of the Vee results in a saving of about half the magneto weight without any loss in dependability. These two engines are worthy of an article by themselves. Suffice it to say, they are the outstanding developments of the year.

In the experimental field there has been a healthy competition. This has centered particularly in the 400 horsepower aircooled field. The Air Service has developed, with the Curtiss Aeroplane and Motor Corporation, a new radial known as the R-1454. This engine is now on its 50-hour test and has shown remarkable performance on a basis of its weight, power, and smoothness of running. Mr. E. T. Jones and Mr. S. D. Heron, in cooperation with Mr. Arthur Nutt, of the Curtiss Aeroplane and Motor Company, have achieved remarkable success in this engine.

Under the Navy's supervision, the Wright Aeronautical Corporation has been developing the Wright radial known as the P-1. This engine has about 200 cubic inches more displacement than the Curtiss radial. It has just finished its 50-hour test with the greatest success. This engine was originally undertaken by the Lawrance Aero Engine Corporation, but with the consolidation of the Lawrance Company with the Wright Aeronautical Corporation, work has continued by Mr. George Mead of that company. In Mr. Mead, the Wright Company has an engineer without superior, as the long line of successful Wright engines will testify.

Important developments have taken place in the field of engine accessories. As a matter of fact, the engines have more or less outstripped their accessories in the past few years and attention is now being focused on these accessories. One of the outstanding developments is the Aeromarine inertia hand starter developed by Mr. Roland Chilton. Mr. Chilton is known in the aircraft engine field as a very clever designer and this hand starter bears out his reputation. In this device, by turning a crank, a high velocity is imparted through gearing to a flywheel. By a suitable tripping device, this flywheel can be engaged with the crankshaft where it exerts enough of the stored-up energy to spin the engine rapidly and start it at once. This starter has been very successful in service. Parallel with this starter development, which was fostered by the Navy, the Air Service has developed satisfactory electric starters of the Bijur type in which provision is also made for hand starting.

One of the difficulties of the past has been found in gasoline pumps. Because of the characteristics of gasoline, it is impossible to lift gasoline from low tanks. The Air Service has overcome this difficulty by using the flexible drive shaft in the Round-the-World cruisers where it was so successful that both the Navy and the Air Service will use it wherever it is indicated. Parallel with this, the Navy has been developing a fuel pump

of unique design. This work has been in the hands of Mr. Warren Noble, of the Kinney Manufacturing Company, who is known for his clever designing of ingenious types of mechanism. In this system, an actuator on the engine transmits pulsations back through the fuel supply line to a spring-operated pump which can be located conveniently. The fuel system is, therefore, much simplified. Tests are now being conducted to determine the reliability of this device.

In the field of ignition, magnetos have replaced battery-generator ignition in a number of installations. Whenever current is required for other purposes, such as landing lights, the battery-generator system may be required. In small airplanes where the current requirements are not great, the magneto ignition holds the field because of its simplicity. Magneto ignition has not been entirely satisfactory insofar as ruggedness is concerned, but it is anticipated that before the close of 1925 this problem will be solved.

Certain parts of the engines themselves have come in for improvement. The outstanding development of the year along this line is the astonishing success of the Allison Engineering Company's steel-backed babbitt bearings. By virtue of its stiffness, steel has proved to be a superior backing for babbitt bearings. These bearings in a Liberty engine greatly increase the life of the engine. It seems likely that they will soon replace all other types in both main and crank pin bearings. The Allison Company has also solved the problem of gears for engines so that now these gears can be built in quantity and of a reliability superior to that of the engine itself.

Under the supervision of Mr. E. T. Jones, Chief of the Power Plant Section, McCook Field, another striking development has taken place. This is in the adaptation of the Moss type supercharger to different engines. The device finds two uses: (1) Supercharging for high altitude work; (2) rotary induction to improve the distribution at low altitudes. The smooth running of the Curtiss R-1454, in which this supercharger, manufactured by the General Electric Company, is installed, is ascribed to this blower. This development has focused attention on the supercharger as a practical service proposition with the result that its employment will be extended in the coming year. Simultaneously with this development, the National Advisory Committee for Aeronautics is working with the Roots type blower at Langley Field and has had great success. This gives a choice of two superchargers for future development.

Higher powers as a result of employing higher compression ratios in engines are dependent upon the development of suitable non-knock fuels. The Bureau of Aeronautics has pushed this development in the past year, but to date has found no absolutely satisfactory solution. A blend of benzol, alcohol, and gasoline serves the purpose but is not entirely satisfactory from a viewpoint of smooth running and easy starting. Benzol-gasoline blends are not entirely satisfactory because the benzol tends to crystallize as ice at low temperatures, and benzol is not available in sufficiently large quantities. Two special fuels are being investigated and while they are sufficiently non-knock, they will need further development before they are entirely satisfactory. It is hoped that continued investigation will produce some results in this important field.

A summary of developments would hardly be complete without a statement of the possibilities of the future. In general, development has taken two forms, (1) the continued refinement and improvement of standard types, and (2) the investigation of interesting experimental types. At McCook Field, the Air Service is experimenting with the Almen, or barrel, engine, and the Cam engine in which a large cam replaces the cranks. The Navy has on order an experimental heavy oil engine for possible use in rigid airships. The success of the Inverted Liberty and the Inverted 1A-1500 engines focuses attention somewhat on the X-type engine. Four banks of four cylinders each in the X-form may be the ultimate compromise between the long in-line engine and the short radial engine.

One of the most promising possibilities, particularly for the watercooled engine, lies along the line of crankshaft speeds in the neighborhood of 3000 revolutions per minute with a 2 to 1 reduction gear giving 1500 revolutions per minute to the propeller and a supercharger capable of maintaining the engine power proportionate to the crankshaft speed. On an increase of not over 15 per cent in weight, such an engine could readily have a 40 per cent increase in power. It is not difficult to imagine that such a power plant in a single engine bomber, similar aerodynamically to the Curtiss or Boeing Pursuit airplanes, will give us, within a few years, speeds of 150 to 160 miles an hour in the heavier types of aircraft quite as readily as we now attain them in pursuit alone.

The statement is made from time to time that the limit in aircraft engine development of the present type has about been reached. About the time this statement is made, however, something like the Packard engine comes along to upset all ideas. In the 1000 horsepower field, an engine having a dry weight of one pound per horsepower is readily attainable any time the necessity for such an engine is apparent. As long as the present designers, such as Mead, Woolson, Nutt, Chilton and Noble are in the industry, it cannot be said that the present type of engine has anywhere near reached its limit. As long as the people responsible for this engine development adhere to the present policy of improving standard types and fostering a healthy development of new types, the future of aircraft engineering in this country is assured.—"U. S. Air Services," February, 1925.

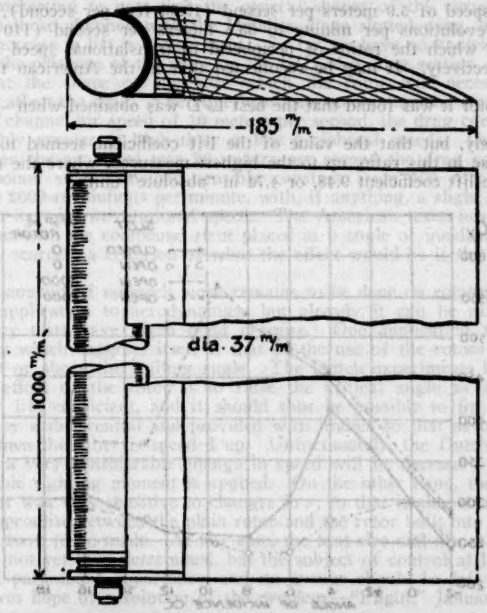
PRELIMINARY STUDY OF THE INFLUENCE OF A ROTATING CYLINDER ON A WING.

Under above heading a most interesting article, by Dr. Ir. E. B. Wolff, appears in the Dutch engineering journal "De Ingenieur" of December 6, 1924. Dr. Wolff is Director of the Rijks-Studiendienst voor de Luchtvaart at Amsterdam, and has been kind enough, upon seeing the interest "Flight" is taking in the subject of the application of the rotor principle to aerodynamics, to call our attention to the article and inform us of further tests that are to be made at Amsterdam.

The experiments described were, Dr. Wolff states, undertaken mainly as a result of certain works by Joukowsky, Bjerkness and Ackeret, which gave Dr. Wolff the idea, after the Delft Conference on Applied Mechanics in April, to make certain tests at the Rijks-Studiendienst, which corresponds to our National Physical Laboratory. As the main problem to be solved was whether or not it would be possible to obtain increased lift from an aeroplane wing by building into its leading edge a rotating cylinder, no attempt was made, during the preliminary experiments, to obtain drag or center of pressure measurements, the lift only being measured. Incidentally, it should be mentioned that when Dr. Wolff undertook the tests he had no knowledge of Herr Flettner's work in Germany, so that it appears that Germany, Holland and the United States have almost simultaneously attacked the problem of the rotor. (An account of the American experiments was published in "Flight" last week.)

The wing section used in the Dutch experiments does not appear to have been a particularly efficient one, but was employed because templates were already in existence, and one section appeared as good as another for the purpose of finding out whether there was a possibility of obtaining increased lift. The overall dimensions of the wing are given in the accompanying diagram, which also shows the method of mounting the rotating cylinder on a spindle. The aspect ratio of the wing itself was low (5.4), so that the low value of the maximum lift coefficient is scarcely astonishing. It is of interest to note

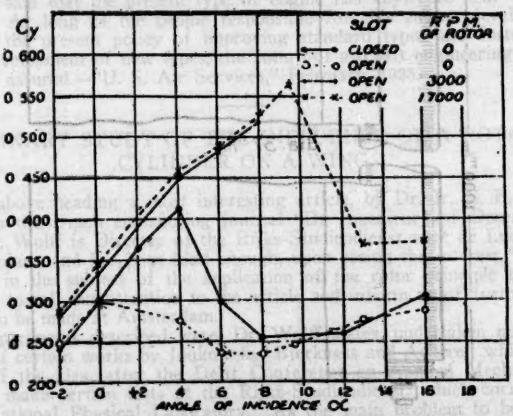
that the ratio of cylinder diameter to wing chord is fairly high, *i. e.*, 20 per cent. It seems likely that future tests may show this ratio to be of considerable importance, and for the sake of efficiency it is to be hoped that a smaller ratio will be found to give as good results. The aspect ratio of the cylinder itself was approximately 27, or roughly twice that of the cylinder tested in America, which had a diameter of 4½ inches and a length of approximately 5 feet.



DUTCH EXPERIMENTS WITH ROTORS: Arrangement and dimensions of the rotor and aerofoil.

The model was suspended in the wind tunnel "upside down," and, as already stated, measurements were made of lift only. The rotor was driven by an electromotor of ⅓ horsepower and was geared up in the ratio 7 to 1. The experiments included readings taken at various air speeds and rotor speeds, at angles of incidence ranging from −2 degrees to +16 degrees. As it was thought that the opening between cylinder and wing section might cause a certain leakage of air, the gap was closed with paraffin wax on the upper surface and the contour smoothed down. This proved to effect a considerable increase in lift over that obtained with the slot open, as will be seen from the accompanying graph, which shows the results at a wind speed of 16.7 meters per second (54.8 feet per second). In the article in "De Ingenieur" the results of the tests are tabulated, but as the graph shows with sufficient accuracy the figures obtained we have not thought it necessary to publish the table.

It will be seen that with the cylinder stationary and the slot open the maximum lift coefficient occurs at an angle of incidence of 0 degrees and has a value of 0.3 (absolute) only. With the upper end of the slot closed this figure is increased to 0.413, and the upper critical angle is increased from 0 degrees to 4 degrees. The other two curves show the lift coefficient at a channel air speed of 16.7 meters per second, and with the cylinder revolving at 3000 revolutions per minute and 17,000 revolutions per minute, respectively. The rotational speed of 3000 revolutions per minute corresponds to a peripheral speed of 5.9 meters per second (19.35 feet per second), and that of 17,000 revolutions per minute to 33.5 meters per second (110 feet per second), at which the ratios of peripheral to translational speed are 0.353 and 2 respectively. It may be recollected that in the American tests with the plain rotor it was found that the best L/D was obtained when $\frac{V^1}{V} = 2.5$ approximately, but that the value of the lift coefficient seemed to increase with increase in this ratio, up to the highest measured, where the ratio was 4.32 and the lift coefficient 9.48, or 4.74 in "absolute" units.



DUTCH EXPERIMENTS WITH ROTORS: Results of wind-tunnel tests. With slot closed and rotor stationary the maximum lift coefficient is 0·42. With the rotor running at 17,000 r.p.m. this value is increased to 0·564, and it is interesting to note that very nearly as good results are obtained with the rotor running at only 3,000 r.p.m. (0·52).

Whereas the American tests on a plain rotor showed the lift coefficient to be very nearly proportional to the value of r (ratio of peripheral to translational speed), the Dutch experiments with a wing section provided with a rotor in its leading edge seem to indicate that this ratio is not critical. Thus with the cylinder rotating at 3000 revolutions per minute, the lift coefficient is 0.522, which is only increased to 0.527 when the rotor speed is 17,000 revolutions per minute. Compared with the section with rotor stationary and upper end of slot or gap closed, the increase in lift is considerable. Below the critical angle of what may be termed the normal wing

section this increase is in the neighborhood of 10 per cent, but when the critical angle has been passed the increase is much greater. Thus the maximum lift coefficient of the "normal" section is 0.413, while with the rotor running at 3000 revolutions per minute the value is increased to 0.522. The upper critical angle is raised from 4 degrees to 8 degrees. When the rotor speed is increased to 17,000 revolutions per minute, the maximum lift coefficient becomes 0.564 at an angle of 9.6 degrees, an increase in lift of 73.3 per cent.

It is interesting to note that the general shapes of the curves are very similar to those obtained with the Handley Page slotted wing, but the percentage increase in lift is not so great. So far we have no knowledge of the effect of the presence of the rotor on the L/D of a wing section. It appears likely that the shape of the nose which the rotor will necessitate may adversely affect the drag. The American tests on a compound strut indicated that, at a channel air speed of 10 meters per second, the drag coefficient was considerably greater at high than at low peripheral speeds. On the other hand, when the air speed was 20 meters per second the drag coefficient of the compound strut remained sensibly constant from 500 revolutions per minute to 2000 revolutions per minute, with, if anything, a slight decrease in drag with increase in rotational speed. The American tests, however, were carried out with the compound strut placed at 0 angle of incidence, and are, therefore, scarcely a criterion of what the effect would be if the angle were altered.

A vast amount of research work remains to be done on rotating cylinders in their application to aerodynamics, but already it can be said that the preliminary tests have given good promise. One application to practical aeroplanes which suggests itself is that of the use of the rotors for lateral control at or above the stalling angle. The Dutch experiments have shown that the effect of the rotor is to raise the critical angle as well as the maximum lift coefficient, and it should thus be possible to fit two rotors, operated by a differential and provided with brakes so that as one rotor is slowed down the other is speeded up. Unfortunately, the Dutch tests indicate that a very considerable change in speed will be necessary before any considerable righting moment is applied. On the other hand, the American plain rotor was very sensitive to changes in r, so that it almost appears that some compromise between the plain rotor and the rotor built into the leading edge will have to be made. At any rate, the best size and disposition of the rotor has not yet been determined, but the subject of control at large angles is one of paramount importance, and no avenue should be left unexplored which gives hope of a solution of the problem.—"Flight," January 15, 1925.

AMERICA'S SUPER-ZEPPELIN.

In our issue of December 18 last, we published a report to the effect that U. S. Naval and Air experts had laid before Congress plans for an airship of about 6,000,000 cubic feet capacity. This week we are able, through the courtesy of our American contemporary, "Slipstream," to give further particulars of this monster airship. These details have been given out by Mr. P. W. Litchfield, Vice-President and General Manager of the Goodyear-Zeppelin Corporation, and may, therefore, be taken as authentic.

Working plans for this super-airship, which will be twice as large as any airship ever built, and slightly larger than the two 5,000,000 cubic feet airships being built for the British Imperial service to India, were started with the arrival in America last year of Dr. Karl Arnstein, formerly chief engineer to the German Zeppelin Co., and a selected staff of twelve technical

men from Friedrichshafen—the birthplace of the Zeppelin. Dr. Arnstein, under whose direction nearly 100 Zeppelins were constructed in Germany, now holds a similar capacity with the Goodyear-Zeppelin Corp., a subsidiary of the Goodyear Tire and Rubber Co., which took over Zeppelin rights for North America.

In answer to the question "Why build an airship of such large capacity as 5,000,000 cubic feet, when smaller ships like the *Shenandoah* and the *ZR-3*, or *Los Angeles*, have shown themselves capable of accomplishing successfully big flights, such as the 9000-mile trip twice across the United States, and the 5000-mile non-stop journey from Germany to America," Mr. Litchfield makes the following statement:

The most important consideration is that the airship reaches its highest efficiency in the larger units. The larger the airship is, the higher is the proportion of useful lift in comparison to size. The earliest Zeppelins carried only from 10 to 20 per cent of their weight useful load, while the *ZR-3*, inflated with gas and under normal temperature and pressure conditions, weighed when empty about 45 tons, but was able to lift a total weight of some 90 tons—or a useful load of 50-60 per cent. A ship twice the size of the *ZR-3* would not require twice the amount of fuel or twice as large a crew, and would thus have a considerable larger percentage of space for passengers, mail, etc. A ten million cubic foot airship could carry a proportionately greater pay load than a five million cubic foot ship. However, it is logical to start first in the intermediate size of a five to six million cubic foot ship and learn what problems are involved there before going to the next step.

In taking up the design of the five to six million cubic foot ship, writes Mr. Litchfield, they are undertaking a new problem, and there are various considerations that must be taken into account. Whether the first requirements of America would be for a military or commercial airship is a primary factor, involving many variations in design.

If the ship is a commercial one, built for speed, then something can be sacrificed in the pay load it may carry. If it is to be built primarily for transport, and the matter of 10 or 15 miles per hour difference in the rated speed of the engines is not important, the engineers must include that fact in their computations. If the ship is designed for travel over-land—say, between the Atlantic and Pacific Oceans—the altitude to be reached or the ceiling of the ship is an important factor, for on the journey from west to east the airship must carry its maximum weight over the Rocky Mountains, and in the higher altitudes the air pressure is less and the temperature is lower, both factors affecting the lifting power of the gas.

If the ship is designed for coast patrol with the fleet, making comparatively short, but fast, scouting trips, it will have different requirements from a ship that is to carry passengers, mail and express across the Atlantic without opportunity for refueling en route. These and other primary facts have to be studied before the final lines of design can be settled, but it is possible to set down in approximate figures at least the general limitations somewhere within which the proposed ship will find itself.

First and foremost the capacity of the gas bags is set at being between five and six million cubic feet. The *Shenandoah* is 680 feet long and 78 feet in diameter. The *ZR-3*, somewhat shorter and fatter, is 660 feet long and 101.6 feet in diameter. This gives a ratio of slenderness for the *Shenandoah* of 8.7, and the *ZR-3* ratio is about 7.2. The proposed super-Zep. may be between 860 and 930 feet long, the maximum diameter 115 to 120 feet, with the overall height from the ground (*i. e.*, including control car) 10 feet more, and with a slenderness ratio of about 7.5.

Let the power required to drive this big ship be set down at 4000 horsepower, as against 1500 horsepower for the *Shenandoah* and 2000 horsepower

for the *ZR-3*. With the engines this size a ship should develop a speed of 80 to 85 miles per hour, and driven at a maximum speed with a full fuel reserve, passengers, freight and mail, should have no difficulty in making a 6000-mile non-stop flight. If driven at a cruising speed of 75 miles per hour, it could go, say, 8000 miles non-stop.

As to pay load, it might carry, say, from 50 to 125 passengers, 3 to 6 tons of mail, and up to 12 tons of freight over these distances.

What will the ship be like? Assume it is designed for overseas transport as a commercial airship, supplementing the steamship service by giving a two-day service between New York and London for that class of passengers to whom time is important and who would make many more trips a year if they could make the round trip to Europe and back in a week or ten days. We may visualize a passenger cabin, extending along the keel of the hull, with a promenade deck and chairs, comfortable berths, dining-room service, shower baths and the like, furnishing a pleasant and easy journey, without sea sickness or other discomforts of present methods of travel.

As regards fares, Mr. Litchfield points out that, while thousands of flights were made by Zeppelin airships in the past, when some 35,000 passengers were carried without accident or mishap, the experience in operating airship services has been too limited to draw final conclusions as to the cost of airship travel.

What may be said is that the Zeppelin airships offer a new and faster method of long-distance transport, and that interesting developments are ahead. America is now able to draw upon the accumulated experience of twenty-five years of the Zeppelin organization in construction and operation of airships. It has the added advantage of American factory methods of construction, etc., plus the fact of a great continent and two great oceans to operate over without having to cross the borders of another nation.

In conclusion, it may be of interest to note that Dr. Hugo Eckener, head of the Zeppelin plant and commander of the *ZR-3* on its delivery flight, will be a member of the board of directors for the Goodyear-Zeppelin Company, his presence and that of Dr. Arnstein and E. A. Lehman (formerly of the Zeppelin Company) being an assurance that the full resources and experience of successful Zeppelin operation will be at America's disposal.—"Flight," February 26, 1925.

WORLD'S RECORDS IN AVIATION.

Last week we referred to the fact that not a single world's record in aviation stood to the credit of Great Britain. We now publish a complete list of the world's records as standing on December 31, 1924, which we have compiled from the official bulletin issued by the F. I. A. From this list it will be seen that the U. S. A. figures very prominently, although a little while back France recaptured one or two records held by America.

CLASS A (BALLOONS).

(a) 600 *cubic m.* (21,192 *cubic ft.*)
Duration.—22 hrs. 34 mins.; France, G. Cormier, August 10-11, 1924.
Distance.—804.173 kms. (499.7 miles); France, G. Cormier.
(b) 601-900 *cubic m.* (—— 31,788 *cubic ft.*)
Duration.—23 hrs. 28 mins.; France, Jules Dubois, May 14-15, 1922.
Distance.—804.173 kms. (499.7 miles); France, G. Cormier.
(c) 901-1200 *cubic m.* (—— 42,384 *cubic ft.*)

Duration.—23 hrs. 28 mins.; France, Jules Dubois.
Distance.—804.173 kms. (499.7 miles); France, G. Cormier.
(d) *All categories.*
Duration—87 hrs.; Germany, H. Kaulen, December 13-17, 1913.
Distance.—3052.700 kms. (1896.9 miles); Germany, Berliner, February 8-10, 1914.
Altitude.—10,800 m. (35,434 ft.); Germany, Suring and Berson, June 30, 1901.

CLASS B (DIRIGIBLES).

Duration.—15 hrs.; Italy, Castracane and Castruccio, on P5, June 25, 1913.
Distance.—810 kms. (493.3 miles); Italy, Castracane and Castruccio, on P5, July 30, 1912.
Altitude.—3080 m. (10,102 ft.); France, Cohen, on Conte, June 18, 1912.
Speed (rectilinear course).—64.800 k.p.h. (40.2 m.p.h.); Italy. Castracane and Castruccio, on P5, July 30, 1913.

CLASS C (POWER-DRIVEN AEROPLANES).

(a) *Records with re-fueling during flight*
Distance, Non-stop.—5300 kms. (3293.5 miles); U. S. A., Lieuts. Lowell Smith and J. P. Richter, on D.H. 4B, 400 h.p., "Liberty," at Rockwell Field (Col.), August 27-28, 1923.
Duration, Non-stop.—37 hrs. 15 mins. 14⅘ secs., *as above.*
Speed.—During the above flight the following speed records were also made:—

2500 kms. (1553.4 miles): 142.780 k.p.h. (88.7 m.p.h.).
3000 kms. (1864.2 miles): 141.870 k.p.h. (88.1 m.p.h.).
3500 kms. (2174.9 miles): 142.170 k.p.h. (88.3 m.p.h.).
4000 kms. (2485.6 miles): 142 k.p.h. (88.2 m.p.h.).
4500 kms. (2796.3 miles): 142.360 k.p.h. (88.4 m.p.h.).
5000 kms. (3107 miles): 142.530 k.p.h. (88.5 m.p.h.).

(b) *Records without re-fueling.*
Distance, Non-stop.—4050 kms. (2516.6 miles); U. S. A., Lieuts. Oakley, J. Kelly and McReady, on U. S. Army T2, 375 h.p. "Liberty," April 16-17, 1923.
Duration, Non-stop.—37 hrs. 59 mins. 10 secs.; France, Coupet and Drouhin, on Farman, 450 h.p. Farman, July 16-17, 1924.
Altitude.—12,066 m. (39,576.5 ft.); France, Callizo on Gourdou-Lesseure mono., 300 h.p. Hispano-Suiza (Supercharger), at Villacoublay, October 10, 1924.
Speed (Ground Level).—448.170 k.p.h. (278.4 m.p.h.); France, Adj. Bonnet, on Ferbois mono., 550 h.p. Hispano-Suiza, at Istres, December 11, 1924.
100 kms. (62.14 miles):—392.379 k.p.h. (243.8 m.p.h.); U. S. A., Lieut. A. J. Williams, on Curtiss R.2C.1, 460 h.p. Curtiss, at St. Louis, October 6, 1923.
200 kms. (124.2 miles):—392.154 k.p.h. (243.7 m.p.h.); *as above.*
500 kms. (310.7 miles):—306.696 k.p.h. (190.6 m.p.h.); France, Sadi Lecointe, on Nieuport-Delage, 500 h.p. Hispano-Suiza, at Istres, June 23, 1924.
1000 kms. (621.4 miles):—205 k.p.h. (127.3 m.p.h.); U. S. A., Lieuts. Harris and R. L. Lockwood, on D.H. 4L, 400 h.p. "Liberty" at Dayton, March 29, 1923.

1500 kms. (932.1 miles) :—184.030 k.p.h. (114.3 m.p.h.) ; U. S. A., Lieut. H. R. Harris, on D.H. 4L, 375 h.p. "Liberty," at Dayton, April 17, 1923.

2000 kms. (1242.8 miles) :—183.830 k.p.h. (114.2 m.p.h.) ; *as above.*

2500 kms. (1553.5 miles) :—115.600 k.p.h. (71.8 m.p.h.) ; U. S. A., Lieuts. Oakley, J. Kelly and McReady, on U. S. Army T2, 375 h.p. "Liberty," at Dayton, April 16-17, 1923.

3000 kms. (1864.2 miles) :—115.270 k.p.h. (71.6 m.p.h.) ; *as above.*

4000 kms. (2485.6 miles) :—113.930 k.p.h. (70.8 m.p.h.) ; *as above.*

Records with 250 *kgs.* (551.2 *lbs.*) *useful load.*

Duration.—9 hrs. 11 mins. 53⅘ secs. ; U. S. A., Lieut. H. R. Harris, on Douglas DT-2, 400 h.p. "Liberty," at Dayton, on June 28, 1924.

Distance.—950 kms. (590.3 miles) ; *as above.*

Altitude.—8980 m. (2945.4 ft.) ; U. S. A., Lieut. H. R. Harris, on T.P.1, 400 h.p. "Liberty," at Dayton, on March 27, 1924.

Speed.—100 kms. (62.14 miles) :—226.272 k.p.h. (140.6 m.p.h.) ; Czecho-Slovakia, Serg. F. Lekhy, on A-12, 266 h.p. Maybach, at Prague, on September 7, 1924.

200 kms. (124.2 miles) :—202.988 k.p.h. (126.1 m.p.h.) ; *as above.*

500 kms. (310.7 miles) :—196.940 k.p.h. (122.3 m.p.h.) ; France, Adj. Foiny, on Potez 15-A2, 400 h.p. Lorraine, at Villesauvage, on November 29, 1924.

Records with 500 *kgs.* (1102.5 *lbs.*) *useful load.*

Duration.—9 hrs. 11 mins. 53 secs. ; U. S. A., Lieut. H. R. Harris, on Douglas DT-2, 400 h.p. "Liberty," at Dayton, on June 28, 1924.

Distance.—950 kms. (590.3 miles) ; *as above.*

Altitude.—8578 m. (28,135.8 ft.) ; U. S. A., Lieut. H. R. Harris, on T-P1, 400 h.p. "Liberty," at Dayton, on May 21, 1924.

Speed.—100 kms. (62.14 miles) :—202.133 k.p.h. (125.6 m.p.h.) ; Czecho-Slovakia, Capt. J. Kalla, on A-12, 260 h.p. Maybach, at Prague, September 7, 1924.

200 kms. (124.2 miles) :—189.219 k.p.h. (117.5 m.p.h.) ; *as above.* Serg. B. Kaspar.

500 kms. (310.7 miles) :—120.550 k.p.h. (74.9 m.p.h.) ; U. S. A., Capt. Louis G. Meister, on Martin Bomber (2) 400 h.p. "Liberty," at Dayton, June 28, 1924.

Records with 1000 *kgs.* (2205 *lbs.*) *useful load.*

Duration.—2 hrs. 13 mins. 49⅘ secs. ; U. S. A., Lieut. J. A. McReady, on Curtiss-Martin NBS-1 (2) 400 h.p. "Liberty," at Dayton, on October 2, 1924.

Altitude.—5751 m. (18,863 ft.) ; France, Lucien Coupet, on Farman Goliath (1) 600 h.p. Farman, at Toussus, May 6, 1924.

Records with 1500 *kgs.* (3307.5 *lbs.*) *useful load.*

Duration.—2 hrs. 13 mins. 49⅘ secs. ; U. S. A., Lieut. J. A. McReady, on Curtiss-Martin NBS-1 (2) 400 h.p. "Liberty," at Dayton, October 2, 1924.

Altitude.—4953 m. (16,245.8 ft.) ; *as above.*

Records with 2000 *kgs.* (4410 *lbs.*) *useful load.*

Duration.—1 hr. 47 mins. 10⅘ secs. ; U. S. A., Lieut. H. R. Harris, on Barling Bomber (6) 400 h.p. "Liberty," at Dayton, October 3, 1924.

Altitude.—4475 m. (14,678 ft.) ; France, Lucien Bossoutrot, on Farman Goliath (1) 600 h.p. Farman, at Toussus, May 8, 1924.

Records with 3000 *kgs.* (6615 *lbs.*) *useful load.*

Duration.—1 hr. 47 mins. 10⅘ secs. ; U. S. A., Lieut. H. R. Harris, on Barling Bomber (6), 400 h.p. "Liberty," at Dayton, October 3, 1923.

Altitude.—1942 m. (6369.7 ft.) ; France, Lucien Bossoutrot, on Farman Goliath (1), 600 h.p. Farman, at Toussus, May 17, 1924.

Records with 4000 *kgs.* (8820 *lbs.*) *useful load.*

Duration.—1 hr. 47 mins. 10⁹⁄₁₀ secs.; U. S. A., Lieut. H. R. Harris, on Barling Bomber (6), 400 h.p. "Liberty," at Dayton, October 3, 1924.

Altitude.—1363 m. (4470 ft.); *as above.*

CLASS C*bis* (SEAPLANES).

(b) *Records without re-fueling.*

Duration.—14 hrs. 53 mins. 44⅘ secs.; U. S. A., Lieuts. F. W. Wead and J. D. Price, on Navy CS-2, 585 h.p. Wright, at Washington, July 11-12, 1924.

Distance.—1600 kms. (994.2 miles); *as above.*

Altitude.—8980 m. (29,454.4 ft.); France, Sadi Lecointe, on Nieuport-Delage, 300 h.p. Hispano-Suiza, at Meulan, March 11, 1924.

Speed (Ground level).—302.684 k.p.h. (188 m.p.h.); U. S. A., Lieut. Cuddihy, on Navy Curtiss C.R., 450 h.p. Curtiss D-12, at Baltimore, October 25, 1924.

100 kms. (62.14 miles):—286.866 k.p.h. (178.2 m.p.h.); U. S. A., Lieut. R. A. Ofstie, on Navy Curtiss C-R, 450 h.p. Curtiss D-12, at Baltimore, October 25, 1924.

200 kms. (124.2 miles):—286.866 k.p.h. (178.2 m.p.h.); *as above.*

500 kms. (310.7 miles):—259.328 k.p.h. (161.1 m.p.h.); *as above.*

1000 kms. (621.4 miles):—163.578 k.p.h. (101.6 m.p.h.); U. S. A., Lieuts. V. E. Bertrandias and G. C. McDonald, on Loening Air Yacht, 400 h.p. "Liberty," at Hampton Roads, November 7, 1924.

1500 kms. (932.1 miles):—119.360 k.p.h. (74.1 m.p.h.); U. S. A., Lieuts. F. W. Wead and J. D. Price, on Navy C.S.-2, 585 h.p. Wright, at Washington, June 23, 1924.

Records with 250 *kgs.* (551.2 *lbs.*) *useful load.*

Duration.—10 hrs. 23 mins. 58 secs.; U. S. A., Lieut. Stanley, on F.-5-L flying-boat, (2) 400 h.p. "Liberty," at San Diego, June 6, 1923.

Distance.—1102 kms. (684.7 miles); Denmark, Karl Lesch, on Rohrbach (metal), (2) 360 h.p. Rolls-Royce, at Circuit du Sund, October 24, 1924.

Altitude.—5691 m. (18,666.4 ft.); Sweden, Lieut. Berndt Krook, on Heinkel S.1, 360 h.p. Rolls-Royce, at Stockholm, August 18, 1924.

Speed, 100 kms. (62.14 miles).—159.151 k.p.h. (98.9 m.p.h.); Denmark, Karl Lesch, on Rohrbach (metal), (2) 360 h.p. Rolls-Royce, at Circuit du Sund, October 24, 1924.

200 kms. (124.2 miles).—158.834 k.p.h. (98.6 m.p.h.); *as above.*

500 kms. (310.7 miles).—156.699 k.p.h. (97.3 m.p.h.); *as above.*

1000 kms. (621.4 miles).—152.335 k.p.h. (94.6 m.p.h.); *as above.*

Records with 500 *kgs.* (1102.5 *lbs.*) *useful load.*

Duration.—7 hrs. 35 mins. 54 secs.; U. S. A., Lieut. H. E. Holland, on F-5-L flying-boat, (2) 400 h.p. "Liberty," at San Diego, June 6, 1923.

Distance.—750 kms. (466 miles); *as above.*

Altitude.—4755 m. (15,596.4 ft.); France, J. F. Laporte, on F.B.A. flying-boat, 300 h.p. Hispano-Suiza, at Argenteuil, August 27, 1924.

Speed, 100 kms. (62.14 miles).—143.118 k.p.h. (88.9 m.p.h.); France, E. Paumier, on Schreck-F.B.A., 350 h.p. Hispano-Suiza, at Argenteuil, November 30, 1924.

200 kms. (124.2 miles).—142.630 k.p.h. (88.6 m.p.h.); *as above.*

Records with 1000 *kgs.* (2205 *lbs.*) *useful load.*

Duration.—5 hrs. 28 mins. 43 secs.; U. S. A., Lieut. Geo. R. Henderson, on Navy P N 7-1, (2) 535 h.p. Wright T-2, at Baltimore, October 25, 1924.

Distance.—400 kms. (248.5 miles); *as above.*

Altitude.—3744 m. (12,280 ft.); France, Buri, on Blanchard, (2) 300 h.p. Hispano-Suiza, at St. Raphael, June 11, 1924.

Speed, 100 kms. (62.14 miles).—126.345 k.p.h. (78.5 m.p.h.); U. S. A., Lieut. Geo. R. Henderson, on Navy P N 7-1, (2) 535 h.p. Wright T-2, at Baltimore, October 25, 1924.

200 kms. (124.2 miles).—126.345 k.p.h. (78.5 m.p.h.); *as above.*

Records with 1500 *kgs.* (3307.5 *lbs.*) *useful load.*

Duration.—2 hrs. 18 mins.; U. S. A., Lieut. H. T. Stanley, on F-5-L flying-boat, (2) 400 h.p. "Liberty," at San Diego, June 7, 1923.

Distance.—100 kms. (62.14 miles); U. S. A., Lieut. O. B. Hardison, on Navy P N 7-1, (2) 535 h.p. Wright T-2, at Baltimore, October 25, 1924.

Altitude.—2130 m. (6986.4 ft.); France, Lieut. Pelletier d'Oisy, on Blanchard, (2) 300 h.p. Hispano-Suiza, at St. Raphael, April 17, 1924.

Speed.—100 kms. (62.14 miles):—100.100 k.p.h. (62.2 m.p.h.); U. S. A., Lieut. O. B. Hardison, on Navy P N 7-1, (2) 535 h.p. Wright T-2, at Baltimore, October 25, 1924.

Records with 2000 *kgs.* (4410 *lbs.*) *useful load.*

Duration.—1 hr. 49 mins. 11$\frac{9}{10}$ secs.; U. S. A., Lieut. O. B. Hardison, on Navy P N 7-1, (2) 535 h.p. Wright T-2, at Baltimore, October 25, 1924.

Distance.—100 kms. (62.14 miles); *as above.*

Altitude.—1489 m. (4884 ft.); U. S. A., Lieut. H. E. Holland, on F-5-L flying-boat, (2) 400 h.p. "Liberty," at San Diego, June 7, 1923.

Speed.—100 kms. (62.14 miles):—110.100 k.p.h. (68.4 m.p.h.); U. S. A., Lieut. O. B. Hardison, on Navy P N 7-1, (2) 535 h.p. Wright T-2, at Baltimore, October 25, 1924.

CLASS D (GLIDERS).

Duration.—8 hrs. 4 mins. 50⅘ secs.; France, A. Maneyrol, on Peyret, at Vauville, January 29, 1923.

Distance.—8.100 kms. (5 miles); France, Lieut. Thoret, on Bardin, at Vauville, August 26, 1923.

Altitude.—545 m. (1787.6 ft.); France, Descamps, on Dewoitine, at Biskra, February 7, 1923.

CLASS G (HELICOPTERS).

Distance, in straight line.—736 m. (2414 ft.); France, Pescara, on twin-screw Pescara, 180 h.p. Hispano-Suiza, at Issy, April 18, 1924.

Altitude, with 100 kgs. (220.5 lbs.).—1 m. (3.28 ft.); France, Oehmichen, on Oehmichen, 180 h.p. Rhone, at Arbouans, September 14, 1924.

Ditto, with 200 kgs. (441 lbs.).—1 m. (3.28 ft.); *as above.*—"Flight," January 29, 1925.

AN OAR-LESS LIFEBOAT.

DESCRIPTION OF THE FLEMING HAND-PROPELLING GEAR FOR SMALL CRAFT.

In the event of shipwreck the only line of immediate escape is that provided by the ships' lifeboats, and after these have been loaded and safely floated immediate danger is by no means over, for it is essential that the boat increases its distance from the sinking ship as quickly as possible. With the ordinary form of lifeboat, propulsion rests solely with the boat crew—the average landsman with an oar of a lifeboat is more often a danger than a help—and even the boat's crew are apt to be upset by the importance of the situation. A practical solution of the problem is provided by the Fleming hand-propelling gear. The arrangement of this gear is shown by the drawing above, which also illustrates the construction of a standard lifeboat of Alfred Holt & Co.'s design.

This gear consists of a series of vertical levers on each side of the boat fitted at their fulcra, about 12 inches below the top of the air tanks, to the

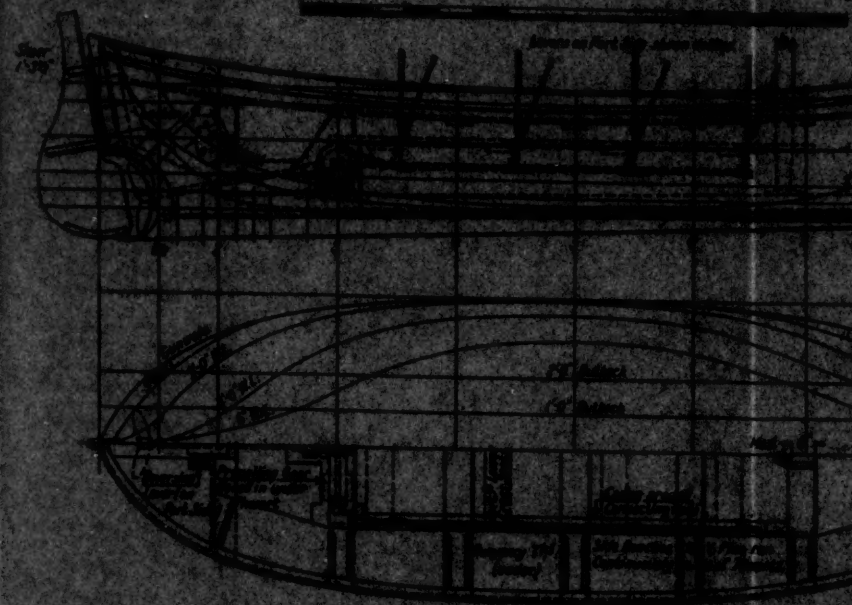
side of the air-tank casing by brackets. These levers are placed between the thwarts and are hinged just above the fulcra, so that when not in use they stow level with the thwart, and therefore do not interfere with the use of oars. The set of levers on each side of the boat are connected at their lower ends to a fore-and-aft rod, and these fore-and-aft rods are, in turn, connected at the after ends to connecting rods which actuate the crank discs which are fitted to a thwartship shaft. On this thwartship shaft, which is placed under the stern sheets abaft the air tank casings, is a wheel geared to a fore-and-aft shaft carrying the propeller.

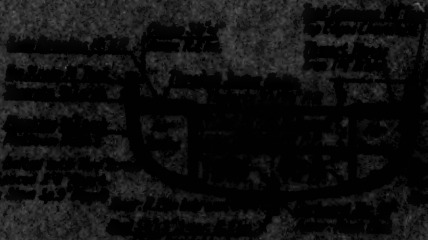
In connection with the thwartship shaft is a reversing gear consisting of a ratchet wheel keyed to the thwartship shaft, and two oppositely arranged pawls, one or the other of which is always engaged in the ratchet wheel so that the propeller can revolve in the required direction, ahead or astern. This direction may be changed by operating the pawls, which is done by a rocking lever. The boat is got under way by moving the vertical levers to and fro. The whole of the mechanism is entirely cased in, but in such a manner that it can be removed immediately for inspection.

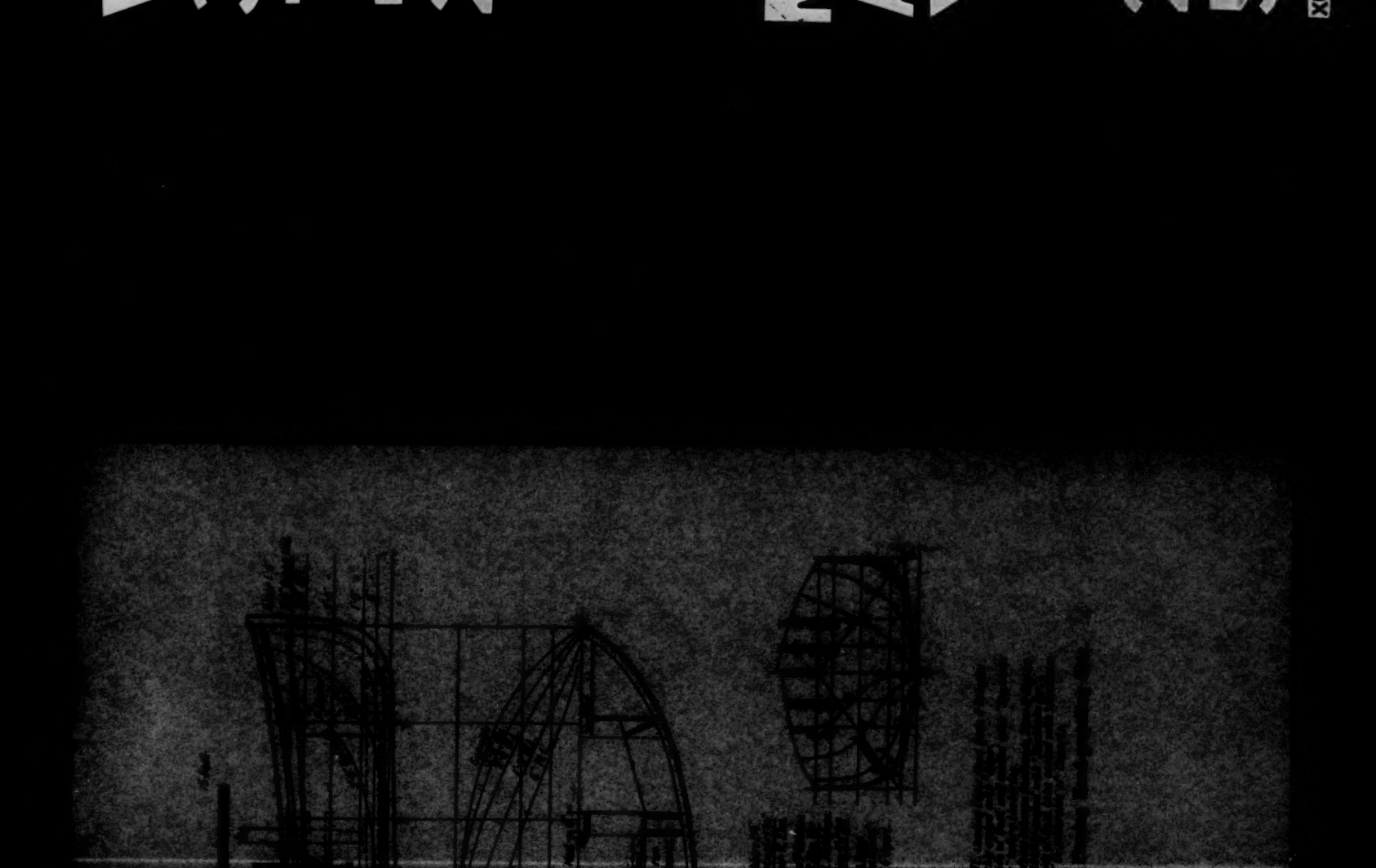
The Mercantile Marine Department of the Board of Trade have fully approved the invention, and boats so fitted are allowed a reduction of 50 per cent in the number of oars carried. The following are the most important features claimed for this system of propulsion. The control of the boat is entirely in the hands of one person, who controls the rudder and, by the reversing lever referred to, converts the direction of travel at will. Therefore, in a lifeboat fitted with this gear, it is necessary only that one man, or at the most two, should have any knowledge of seamanship; the remainder of the passengers may be either men or women, who are equally capable of working the propelling gear without any previous knowledge or experience. Also, when the boat is afloat and the falls are released, the craft can immediately be put in motion and got away from any imminent danger. Other important features are that, owing to the absence of oars and the necessary working space, an additional number of passengers can be carried comfortably and the craft can easily be kept head on to the sea at all times.

The Blue Funnel Liner *Hector* is equipped with a lifeboat fitted with the Fleming hand-propelling gear, and at the invitation of the owners, representatives of Lloyd's Register, the Board of Trade, the British Corporation and several shipping companies, visited the vessel at King George V Dock on Thursday, January 22, to witness a demonstration of the gear. The lifeboat was first propelled round the dock by a number of the crew and then, with 42 people aboard, a series of tests were made. It was found that with two people at the levers, one on the port side and the other on the starboard side, the craft could be immediately got under way, and with a man at each lever, eight men in all, a speed of about 4 knots could be maintained. The lifeboat on the *Hector* was stowed under davits invented by Mr. George Turnbull, of the Blue Funnel Line. Considerable interest was aroused by the efficient working of these davits, which are termed the "one-man davit," and for further details we refer readers to the detailed description which appeared in "Shipbuilding and Shipping Record," June 1, 1922 (page 721). Following the demonstration of the lifeboat, the guests were entertained at lunch on board the *Hector* by Captain E. Worlidge, Marine Superintendent in London of the Blue Funnel Line. Captain Warden and Captain Millett expressed the thanks of those present for the opportunity of witnessing the demonstration and the hospitality afforded them.

The gear is manufactured and fitted by I. R. Fleming & Co., 227 and 228 Tower Building, Water Street, Liverpool, and it is claimed that any existing lifeboat can be fitted with only slight alteration.—"Shipbuilding and Shipping Record," January 20, 1923.







CORROSION AND EROSION OF STEAM TURBINE BLADING.

The production of suitable material for turbine blading is a problem of increasing importance, particularly for high-speed turbines. In the "Brown Boveri Review" for December, 1924, Dr. E. Honegger describes a series of experiments on the corrosion and erosion of steam turbine blading; he points out that blades are worn as the result of either corrosion or erosion, or of a combination of both.

In the high-pressure regions of turbines the blades only come into contact with superheated steam, so that the risk of corrosion during operation is slight, and if sufficiently hard material is used there is no erosion. For impulse turbines, 5 per cent nickel steel, and for reaction turbines, brass and similar alloys are satisfactory.

In the low-pressure region the problem becomes much more difficult. The particles of water suspended in the wet steam cause erosion, which may be assisted by corrosion when the material is liable to it. It is with this danger that Dr. Honegger deals.

For low and medium speeds many materials are available; 72/28 brass is very suitable, and, as brass does not rust, such blades can be used for many years without signs of wear. Monel metal is also of great value, as its strength is practically independent of temperature changes, and it is highly resistant to erosion and corrosion.

For blade speeds higher than about 600 feet per second, the choice of a suitable material is more difficult, as erosion increases with the velocity of the blade, and, even after a few hours, brass blading shows signs of wear, and soon breaks down. The back rather than the front of the inlet edge of the blade usually wears, and that part furthest away from the center is most severely attacked; this is due to the fact that the small particles of water suspended in the steam are thrown towards the tips of the moving blades and the roots of the stationary blades by centrifugal action.

Another cause of erosion is the use of higher steam pressures without a corresponding increase in the exhaust pressures. As a result more water is present in the steam, and a greater part of the turbine operates on wet steam.

It will thus be seen that soft metals such as brass are useless for the last row of blades in limit turbines, and harder materials, such as alloy steels, must be used. The alloys recently developed under the name of "stainless steels" are suitable, as they are highly resistant to corrosion and erosion. Some of these steels, however, are very difficult to work, and, as the blades have to be made with great accuracy, must be rejected on that account.

Messrs. Brown Boveri and Co. have carried out extensive researches on these materials, as compared with brass and Monel metal. In the preliminary tests, the results of which are summarized in the table below, taken from Dr. Honegger's paper, very severe conditions were chosen so as greatly to accelerate the attack on the blade material. Specimens of the various metals selected for test were machined to the form of prisms, the cross section being 10 millimeters square, with surfaces milled and finished on a grinder. They were arranged in front of a steam nozzle, so that the jet impinged on the two faces of the prism, the axis of the jet making an angle of 30 degrees with one face and 60 degrees with the other. (Fig. 1.)

Further tests were carried out on specimens drawn down to blade section and set up so that the steam jet struck the back of the blade at a sharp angle. (Fig. 2.)

Copper lacing wire with a steel core was soldered to some of the blade specimens, hard and soft solder being used alternately. Dry saturated steam at about 140 pounds per square inch was employed, and was expanded in the

Material.		Chemical composition.											Brinell No.	Loss due to immersion for 120 hours in 10 per cent. acid solution.				Loss due to erosion.	
Description.	Heat treatment.	Cu.	Zn.	Ni.	Mn.	Fe.	Cr.	Si.	S.	P.	Pb.	C.		H_2SO_4.	HNO_3.	HCL.	Total.	Duration of test.	Loss in w'ght.
														Loss of weight in grammes.				Hours.	Gr.
(1) Rustless chrome steel ..				1.49	0.33		12.7	0.49	0.03	0.04		0.14	232	14.73	0.12	18.10	32.96	66	0.22
(2) Stainless steel				0.42	0.16		11.3	0.22	0.09	0.03		0.33	229	20.0	0.93	19.66	40.59	69	0.27
(3) Stainless steel	Heated to 825° C. and quenched in oil												402		Not determined	Not determined		68	0.04
(4) Special nickel steel ..				10.2	0.44		0.14	0.25	0.013	0.014		0.15	229	0.66	12.45	0.90	14.03	69	0.48
(5) Special nickel steel ..	Heated to 825° C. and quenched in oil												338		Not determined	Not determined		68	0.12
(6) Special chrom-nickel steel				21.38	1.05		2.06	1.47	0.005	0.034		0.72	197	0.06	10.85	0.06	10.97	69	0 02
(7) Nickel steel				7.01	0.27			0.27	0.028	0.025		0.10	163	0.41	12.41	0.46	13.28	67½	1 04
(8) Nickel steel	Heated to 825° C. and quenched in oil			5.04	0.27			0.22	0.034	0.014		0.12			Not determined	Not determined			
(9) *Brass (drawn)		72.6	27.06			0.15					0.1	Sn 0.1	80	3.04	10 51	0.17	13 72	71	2.43
(10) *Monel metal (drawn) ..		29.17	0.3	66.3	1.64	2.9		0.1				0.32	122	0.08	0 15	0.22	0 45	71	0 48

* As specimens of 10 × 10 cm. section could not be obtained from the material available, a number of pieces of these metals were laid together to make up the required thickness. Therefore the results obtained are not strictly comparable with the remainder.

nozzle down to a vacuum of 26 inches of mercury. The adiabatic heat drop was thus 163 units, and the steam velocity 1100-1200 meters per second.

The erosion of each specimen was determined by the loss in weight resulting from an exposure of about 70 hours to the steam jet. The results are given in the accompanying table, together with the chemical composition and the Brinell number of the materials.

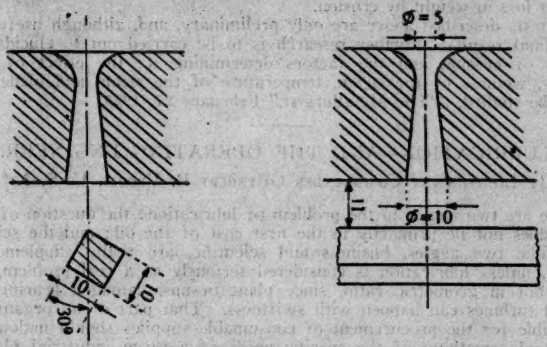


FIG. 1.

In every case the surfaces inclined at 30 degrees to the axis of the steam jet showed more erosion than those at 60 degrees; it is suggested as a possible explanation that a thin protective layer of steam or water may form over the surface on which the steam impinges more directly. The soldering

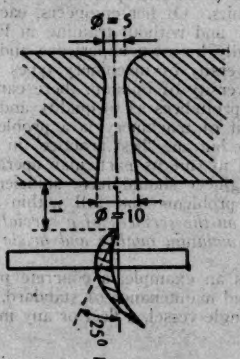


FIG. 2.

process did not appear to have affected the metals, but the soft solder was completely washed away, while the hard solder connections were satisfactory.

The stainless steels (2) and (3), and the special nickel steels (4) and (5) show that increased hardness imparted by heat treatment results in a greater resistance to erosion. The special chrome-nickel steel (6) is an example of an alloy steel of high tenacity and elasticity and more than average hardness which is highly resistant to corrosion. Such a steel is not at the present

time suitable for turbine blades, as it is very difficult to work, but if this difficulty could be overcome it should prove of great value. It is similar to the rustless chrome steel (1) and the stainless steel (2), which have excellent resistance to nitric acid. On the other hand, the nickel steels (7) and (8) and the special chrome steel (6) dissolve in this acid.

As was to be expected, brass (9) and Monel metal (10) showed the greatest loss in weight by erosion.

The tests described above are only preliminary, and, although useful, lead to no final results. Further research is to be carried out to elucidate the process of erosion and the factors determining it; the effect of steam velocity, wetness of the steam, temperature of the steam and blade angle are to be studied.—"The Metallurgist," February 27, 1925.

LUBRICATION—AND THE OPERATING ENGINEER.

By Lieutenant Commander Guysbert B. Vroom, U. S. N.*

There are two angles to the problem of lubrication: the question of costs, which does not lie primarily in the first cost of the oil; and the scientific side. The two angles, business and scientific, are really supplementary, because, unless lubrication is considered seriously as a real problem, costs can mount in geometric ratio, since plant tie-ups, damaged bearings and stripped turbines can happen with swiftness. That part of an organization responsible for the procurement of consumable supplies should undoubtedly understand something of the specific needs of a given industrial plant or ship, the sources of expert advice as to specific requirements and, as a matter of efficient administration, the methods of ensuring maintenance of supply as to quality and grade, to the end that, once the particular requirements are established, there shall be no experimentation or admission of individual predilection or prejudice.

A vessel may be taken as an example, since her machinery will include a number of diversified units. Of her engineers, each one, trained largely in the school of experience and without training in lubrication engineering as a specialty, will have only his own experience and rule of thumb methods as a guide. With a diversity of machinery types to care for and operate, and an equally large diversity of opinion, there cannot but be variations of operating methods, and prejudices as to quality and grade of lubricants. It is obvious that each unit of machinery is a problem in itself, and equally obvious that there can be but one "best practice" in the selection of a proper grade and quality of oil to suit its particular operating conditions. Therefore, the responsible engineer should have sufficient specialized knowledge to solve all lubrication problems that fall within his jurisdiction; or, *the management should call on the services of a specialist, to determine the best practice, and thereafter maintain quality and grade by means of laboratory check on deliveries.*

Still using a vessel as an example, a concrete plan can be exhibited, to insure correct practice and maintenance of standard. The plan is, of course, equally applicable to a single vessel, a fleet or any industrial plant considered as a unit.

MACHINERY UNITS SHOULD BE LISTED.

The first step is the preparation of a list of machinery units, showing the working conditions of each unit. The conditions would include data covering speed, average and maximum temperatures of bearings, pressure and size of bearings, clearances, forced or hand feed, cooling system in use, whether an oil purifier is used, size of oil piping.

* Member, American Society Naval Engineers.

This list, then, would form the basis upon which to proceed to the selection of the several grades of oils for the plant. Necessarily the most important units, such as main propulsion, circulating pumps, feed pumps, blowers, etc., would be considered first, and any compromise should favor those units of the greatest value and relative importance. It is not to be expected that there can be as many grades of oil supplied as there are units; two or three grades, properly selected, should suffice.

SELECTION OF THE LUBRICANT.

The selection should be strictly on the basis of quality, involving chemical characteristics to insure a well refined oil containing no impurities, and on *viscosity*, to insure proper grade. Successful lubrication, all other things being equal, including proper design, depends upon viscosity, since this physical characteristic is a measure of the ability of the oil to maintain a film, under given conditions of pressure, temperature and speed of bearing.

Quality should be considered from the standpoint of conditions governing the plant as a whole, and peculiar to the service in general. Thus, as an illustration, a turbo-generator unit on board ship should be supplied with an oil that will resist emulsion, if contaminated with salt water, because a leak in the water service to the oil cooler or bearings may bring about this condition at any time; a condition that would not apply to shore practice. On the other hand, all force feed oils should resist emulsion when in contact with steam or fresh water, which can, and does, happen both ashore and afloat.

From the standpoint of quality, the best is the cheapest, and by the *best* is not meant that oil which is the most expensive, or the most widely advertised, or even that which may be recommended by the builder of the machinery. The best is that oil which, by actual analysis and examination, is known to be free of chemical impurities that are potential sources of far reaching and costly damage, through the breaking down of the oil under service conditions peculiar to the plant as a whole. From the standpoint of *viscosity*, the best is that grade, or grades, requisite to maintain lubrication under the service conditions of the several units peculiar to their design. One of the difficulties of selection lies in the unscientific designation of the many trade brands on the market. A "medium" oil marketed by one producer may be quite different from the medium oil of another. Again, various companies use compound words descriptive of their own products only, such as light-medium, medium-heavy, etc. For these reasons, viscosity should be specified in scientific terms, based on a widely known standard. There can be no doubt in the mind of the producer, or the consumer, when an oil is described as "Viscosity Saybolt 125-145 seconds, at 130 degrees F." The scientific description should invariably be used, and no oil purchased except under that description. The list of units should bear, for each entry, the grade of oil required, based on viscosity.

REDUCE NUMBER OF GRADES TO MINIMUM.

The next step should be a scrutiny of the list to reduce the number of grades (viscosities) to the fewest possible, consistent with good practice, favoring the important units where compromise is essential. Tankage and storage facilities available will govern this factor; there are other considerations also, such as increased chances for contamination, possibility of errors in use, cost of handling and waste, to be considered.

If the responsible operating engineer of a plant or vessel has not sufficient technical knowledge to investigate requirements and specify practice as thus far outlined, the management should seek the services of a consulting engineer and consider the cost as money well spent. Further, having once established standard practice, an annual check-up of conditions should be

made, also by a consultant, because modification of practice may be desirable due to wear-down of bearings, particular design of lubricating systems which may require slight change or even redesign, or other modification of conditions.

BUY BY SPECIFICATION ONLY.

We now come to the business angle. The procurement of lubricants, and for that matter all consumable supplies, should be strictly in the hands of the management or purchasing department of the organization (except, of course, emergency purchases at out-of-the-way ports, in the case of vessels). Purchases should be by *specification* only, based solely on the known technical requirements. It is a fair assumption that the large producers and distributors of petroleum products are on an equal footing as to availability of supplies of crude oil, that they are equal to the production of similar products, and that the production methods are, by this time, pretty well standardized throughout the trade. All companies maintain a consulting field service, but the difficulty is that their recommendations are, of course, based on their own company's products, which are sold under their own brands and nomenclature, so that, if their recommendations are followed, competition is restricted. Hence the desirability of employing a consultant.

Recommendations of manufacturers of machinery as to *brands* should not necessarily be followed, because, again, competition is ruled out, and further because it is contrary to sound practice, for if the manufacturer goes out of business, changes his brand name or the quality of the brand, then both the manufacturer of the machinery and the user thereof are in the dark.

Competition based on scientific specification assures the consumer freedom from that uncertainty that must exist if purchases are made on trade designations and standards which, as has been pointed out, vary with the several producers and are subject to change without notice.

LABORATORY TEST CHECKS ADVISABLE.

Purchase on specification alone is not sufficient. Once established, the standard should be maintained by laboratory check, from time to time, of samples from deliveries under contract. The cost of such check is small, compared to the value of the machinery involved, and insures not only proper delivery, which, of course, it is to be assumed will be made in good faith, but also against errors that are bound to occur and against contamination in transit or after delivery.

The following outline sums up the practice discussed in this article and shows a typical plan of procedure and practice:

MACHINERY LIST—S. S. "RISING STAR."

Machinery units	Speed	Temperature		Bearings		Oil recommended
		Average degrees	Maximum degrees	Size	Clearance inch	
Turbines, geared	1400	130	180	8×10	0.05	"Medium" Vis. 125-145 at 130 degrees F. (Saybolt)
Turbo-generators, direct connected	1800	110	135	6×8	0.03	"Light" Vis. 100-115 at 130 degrees F. (Saybolt)
Feed pumps, rotary	100	150	200	3×3	0.04	"Heavy" Vis. 180-200 at 130 degrees F. (Saybolt)

This shows the general plan of a list or machinery index, in outline. It should, of course, contain, in detail, all pertinent information that affects lubricating conditions of each unit.

Having determined upon the grades, by viscosities, the next step is the preparation of the specification. This should cover the chemical and physical requirements peculiar to the service in general; in the example, a sea-going vessel.

TYPICAL SPECIFICATION.

Forced Feed Oils.

SPECIFICATION—Oils offered shall show freedom from the following: Mineral acid, fixed or fatty oils, matter insoluble in gasoline, free sulphur, sulphur compounds, SO_3 as sulphonates, water, ash.

Organic Acid, not greater than 0.10 per cent.

Matter soluble in cold H_2SO_4, not greater than 10 per cent.

Carbon residue, not greater than 0.5 per cent.

Evaporation loss per cent, not greater than 2.5.

VISCOSITY AND GRADE.

"Light"	"Heavy"	"Medium"
100-115 secs.	180-200 secs.	125-145 secs.
Saybolt at 130 degs. F.	Saybolt at 130 degs. F.	Saybolt at 130 degs. F.

CHARACTERISTICS.

Nature of Oil	Mineral	Mineral	Mineral
	Degrees F.	Degrees F.	Degrees F.
Flash above	340	350	345
Fire	370	380	370
Pour below	32	32	32

Oils shall separate out within ½ hour when emulsified with

Distilled Water
1 per cent Salt Solution
Normal NaOH
Boiling Water
} at 130 degrees F.

and within 1 hour when emulsified with steam.

The above shows a typical specification, understandable alike by producer and consumer, which can, of course, be varied as necessary to suit particular requirements, as recommended by a consultant, or determined by the plant engineer.

Having determined upon the practice and the specification to fit it, the procurement and maintenance of standard is a matter of ordinary business management. Having agreed to the specification, the successful bidder or supplier should be required to guarantee deliveries in accordance with the specification. Check tests, from time to time, should, of course, be made, using samples taken from deliveries.

Samples should also be taken from oil *in use* at stated periods, not only as a check upon the particular lubricant in use, to see if it stands up, from a chemical point of view, without break-down of its important constituents; but also to insure freedom from contamination from external sources, or which may be detected and remedied. Such periodic examination is worth the expense and effort to insure that the consumer is obtaining his oil according to contract specifications, and will in the end avoid machinery breakdown and consequent expense.—"Marine Engineering and Shipping Age," April, 1925.

OPERATING CENTRIFUGAL PUMPS IN COMBINATION.

By Russell K. Annis.

The question is often asked, "How can I increase the capacity of my centrifugal pumping outfit? I would like to add another pump, but do not know whether I need more pressure or just more pump capacity." A description of the present pump is generally given, and it is desired either to purchase a new pump to use with it, or to use to the best advantage another pump that is already at hand.

There are two general methods of connecting a new pump into a line in order to increase the capacity, and one of these, known as the "series" arrangement, is shown in Fig. 1. When pumps are connected in series, the

Fig. 1.—Two Pumps Arranged in Series.

discharge of one is connected into the suction of the next, and the same water passes through each pump, the resulting pressure being the sum of the pressures of the two pumps.

The other arrangement, known as the "parallel" connection, is shown in Fig. 2. Here the heads against which the two pumps act are necessarily the same, and the total capacity is the sum of the individual capacities.

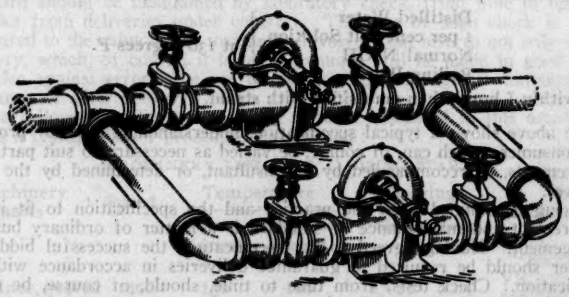


Fig. 2.—Two Pumps Arranged in Parallel.

It can be seen that these two forms of connection are the same as series and parallel connections for electrical machines. The results obtained from connecting pumps in combination are also analogous to electrical machines, in that the series connection is used to build up pressure for pumps and electrical pressure, or voltage, for generators; while the parallel connection increases the rate of flow for pumps, which is the equivalent of ampères of current in a generator.

Sometimes, however, it is necessary to increase the pressure in order to get increased capacity, while, on the other hand, the capacity can sometimes be increased directly by using the parallel connection. In other words, there is no general answer to the question of increasing the capacity of an outfit; sometimes a series connection is better and sometimes a parallel, and the decision can be made only by correctly analyzing the conditions.

EACH CASE MUST BE STUDIED SEPARATELY.

A case has been known where a small pump was added to the discharge line of a large pump, making a series connection with it, and this caused a decrease in capacity, owing to the smaller passageways in the small pump. The small pump was then taken out and connected across the large pump, making a parallel connection, again resulting in decreased capacity, this time due to the fact that the small pump could not maintain the line pressure equal to the large pump, and the water was flowing through it in a reverse direction. In a case of this kind it is impossible to get satisfactory results by either method, and if the conditions had been analyzed beforehand, much trouble could have been avoided.

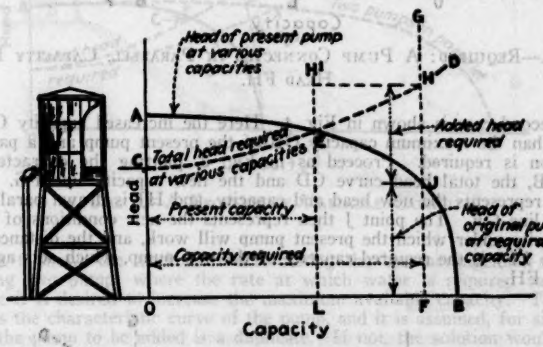


FIG. 3.—THIS SOLUTION SHOWS THAT A PUMP IS NEEDED IN SERIES, CAPACITY OF, HEAD JH.

One solution to this problem is shown in Fig. 3. When the conditions are such that this method can be used, the new pump should be arranged in series with the present pump. The characteristic curve of the pump—that is, the relation between head and capacity—is represented by AB. The curve showing discharge pressures at various capacities is represented by CD. The curve CD crosses AB at E, which must be the head and capacity at which the present pump is operating. In other words, the present capacity is OL, and the pressure LE.

The capacity to which it is desired to increase the outfit is represented by OF. The line FG is now drawn perpendicular to the base line. This intersects AB at J, and it also intersects CD at H. The point H represents the new head and capacity of the outfit, and the distance JH represents the head that the new pump will be required to develop, while FJ represents the head which the present pump will develop at the new capacity.

SOMETIMES PARALLEL CONNECTION IS BETTER.

It sometimes happens that EH' is specified as the head required for the new pump, but this is not correct, as it takes into account only the increase in friction, but not the decrease in the head developed by the present pump.

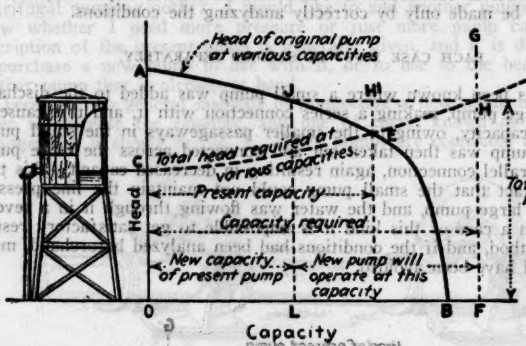


FIG. 4.—REQUIRED: A PUMP CONNECTED IN PARALLEL, CAPACITY LF, HEAD FH.

The second case is shown in Fig. 4. Here the increased capacity OF is greater than the maximum capacity OB of the present pump and a parallel connection is required. Proceed as in Fig. 3, plotting the characteristic curve AB, the total head curve CD and the new capacity line FG. The point H represents the new head and capacity, and HJ is drawn parallel to the base line OF. The point J then represents the new conditions of head and capacity under which the present pump will work, and the distance JH (equal to LF) is the required capacity of the new pump, which acts against the head FH.

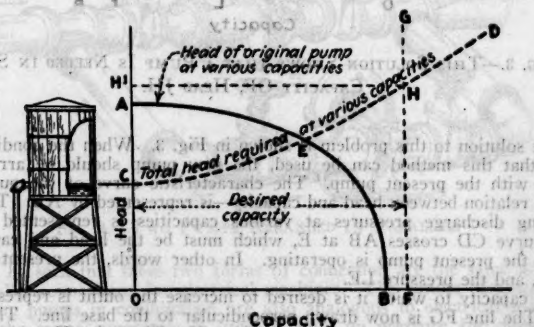


FIG. 5.—PRESENT PUMP CANNOT BE USED. NEW PUMP REQUIRED, CAPACITY OF, HEAD OH'.

The two pumps should be connected in parallel, and they will both work against the same head FH, the present pump developing a capacity of OL and the new pump a capacity of LF. The actual added capacity will be HH', but the capacity of the new pump must be greater than this by an amount represented by H'J, due to the loss in capacity of the present pump when working against the increased head.

Another condition is shown in Fig, 5. In this case neither of the perpendiculars from the point H intersects the characteristic curve AB, and there is no solution. In other words, there is no possible way to use the pumps in combination, and a new pump will have to be used that is capable of developing both the head and the capacity represented by the point H.

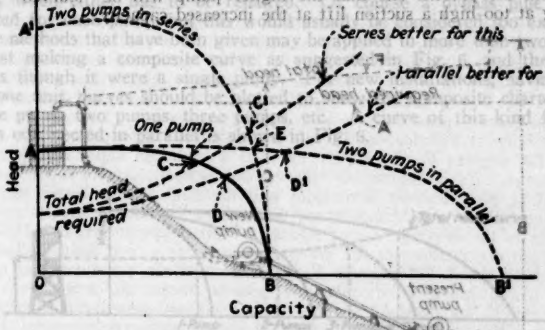


FIG. 6.—A PROBLEM OF VARIABLE CAPACITY.

Fig. 6 shows the method of determining the best arrangement for connecting two pumps where the rate at which water is required varies and where it is desired to increase the maximum available capacity. The curve AB is the characteristic curve of the pump, and it is assumed, for simplicity, that the pump to be added is a duplicate. If not, the solution would be the same.

CONNECTING TWO PUMPS FOR MAXIMUM CAPACITY.

The curve A'B is plotted in by adding together the heads produced by the two pumps at various capacities. The result is the combined characteristic for both pumps in series. Similarly, the curve AB' is the characteristic curve for the pumps when arranged in parallel, and it is plotted by adding together the capacities of the two pumps at various heads.

The point E, where the two curves cross, represents the one condition that could be obtained by arranging the pumps either in series or in parallel. For greater capacities than that represented by E, the pumps should be arranged in parallel, but if a greater head is required, a series arrangement should be used. A good method for determining whether the head is great enough, is to plot out on cross-section paper a diagram similar to Fig. 6 and note where the total-head curve crosses the combined curves. If it crosses above the point E, as at C', use a series arrangement. On the other hand, if it crosses at D', to the right of E, use the parallel arrangement.

In cases where the friction is negligible, the position of the required head with relation to the point E determines the best arrangement. If the required head is greater than E, use the series arrangement; if less than E, use the parallel.

Fig. 6 merely shows how to determine the *maximum capacity that may be expected*, from two pumps whose characteristic curves are known, while the other method showed *what size of pump was required* to obtain a given condition of head and capacity.

Sometimes, as in the case of mine work, it is desired to add a new pump at a point somewhat distant from the present pump, usually as close to the entrance of the mine as possible to reduce the electrical resistance, and also in order that repairs may be made more conveniently. This, of course, requires a series connection. The new pump should not be placed so far away from the present one that the higher pump will be "starved" from operating at too high a suction lift at the increased capacity.

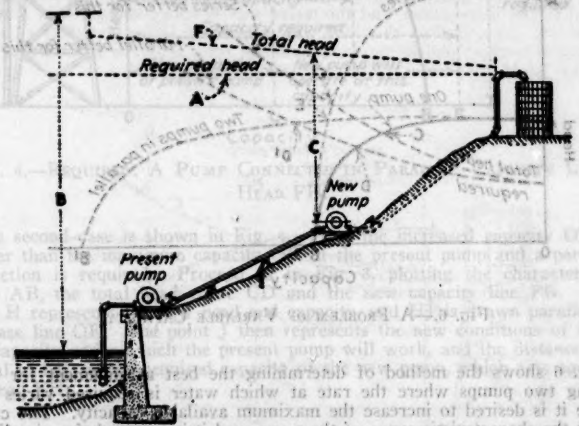


FIG. 7.—TWO PUMPS IN SERIES AND LOCATED SOME DISTANCE APART.

This condition can be avoided by plotting out the curves as shown in Fig. 3, and then the new pump can be placed at such a point above the present one that the head as indicated by FJ will not be exceeded.

ARRANGING TWO PUMPS IN SERIES.

In Fig. 7, which shows the arrangement of two pumps located at some distance from each other, A is a horizontal line drawn from the point of discharge, and F is a line plotted above this to allow for the pipe friction at any point. Then B is the total head against which both pumps will act, and C is the head of the new pump. B minus C is the new head for the present pump, and it must not be greater than the head represented by FJ (Fig. 3).

Where pumps are connected in series as in Fig. 1, the larger pump should be located in the line first, discharging into the suction of the smaller. With this arrangement a full supply of water will be assured at all times. If the smaller pump were placed first, it might prove to be an impediment in the suction line of the larger.

In some cases, where the supply is variable, the new pump is arranged for automatic operation. This is a good plan. However, where the connection is parallel, a check valve is required on the automatic pump. Do not put a check valve on the continuous pump, unless its head is at all capacities greater than the intermittent one. If the continuous pump is a lower-head pump than the intermittent, and a check valve is used, the discharge from the small pump will become completely shut off when the intermittent pump starts. The resultant churning will overheat the pump.

From a maintenance point of view, wherever one connection will give practically the same results as the other, the parallel method is preferred. When pumps are connected in this way, it is possible to repair either pump while the other is running. Shutoff valves should be provided for this purpose. With the series arrangement it is necessary to shut down both pumps when either has to be repaired. Of course a bypass pipe can be installed for each pump, but this would usually be considered too expensive.

The methods that have been given may be applied to more than two pumps, by first making a composite curve as suggested in Fig. 6, and then using this as though it were a single pump. For new installations, having more than one unit, curves should be plotted to show the composite characteristic of one pump, two pumps, three pumps, etc. A curve of this kind for four pumps connnected in parallel is shown in Fig. 8.

FIG. 8.—COMBINED CURVES OF PUMPS IN PARALLEL.

A precaution that should always be taken when making any change on the pipe line of a centrifugal pump is to check up on the efficiency at the new conditions. It may be so low as to be very uneconomical, or the motor may be overloaded. This statement relates especially to a pump where another is added in series with it, because all the increased capacity goes through it, and the power requirements are usually increased. Overloading is not so likely with parallel connection.

Aside from the advantage of adding a pump to a line already installed, there are several reasons why it is desirable at times to use more than one centrifugal pump on a single line. For instance, where a variable supply is wanted, two small pumps are better than one large one, because each can be used at its most efficient capacity to suit the demand. If the demand is small, one pump can be used, and as the demand increases, others can be started up. Another advantage of more than one unit is that in case of repairs pumping service will be lessened without being entirely discontinued, as would be the case with one large pump.

Again, a pump may be already installed and found not to be adequate at all times. It may be wiser and cheaper to buy another small unit than to replace the present pump with a larger one. The larger pump may be slightly more efficient, but if all the advantages of a duplicate unit are considered, pumping costs may actually be lower by installing another small pump.—"Power," March 3, 1925.

MERCURY VAPOR PROCESS.*

By W. L. R. Emmet, Sc.D.,
General Electric Company.

The process described in this lecture has been undergoing experimental development for some years, and, for the last year, has been operating in a large experimental installation in a plant of The Hartford Electric Light Company.

The purpose of this process is to obtain improved thermodynamic efficiency from fuel through the use of a greater temperature range than is practicable with steam.

While the efficiency of thermodynamic processes is limited by many peculiarities of the substances used, they are generally dependent upon the temperature range and, since with steam turbines we work effectively down to the lower temperature limit as established by our cooling water, we must look for substantial gains to the use of higher maximum temperatures than have been used with steam. With this end in view, higher and higher steam pressures have been used and superheating and reheating of steam to the maximum degrees possible have been considered.

Water boils at 212 degrees F., has a pressure of 3200 pounds per square inch at 706 degrees F., and cannot exist as a saturated vapor at any higher temperatures. As it approaches this critical temperature its latent heat of vaporization progressively diminishes and the heat in the liquid increases. These peculiarities and temperature limitations introduce certain practical difficulties in the effective use of steam to high temperatures, in addition to those which are incident to the excessive pressures which must be handled.

Mercury boils at 677 degrees F. with atmospheric pressure, and at 706 degrees has a pressure of only five pounds above the atmosphere. At 900 degrees F. its pressure is only eighty pounds above the atmosphere. Throughout this entire range, its heat of evaporization only varies slightly and the heat in the liquid is relatively very small, which qualities excellently adapt it to thermodynamic purposes.

In this process, mercury is vaporized in a boiler from which it is conveyed in a pipe to a turbine which drives a generator. On exhausting from this turbine at a vacuum pressure, it delivers its heat of vaporization to tubes in which high pressure steam is thereby generated. This steam can be applied to any purpose. After condensing on this steam-making surface the liquid mercury runs back by gravity into the boiler where it is again vaporized. With a view to cost reduction, the boiler is designed to operate on a very small volume of mercury and the total quantity may be vaporized nine or ten times in an hour. The furnace gases, after passing through the mercury boiler, are carried through a heater to raise the temperature of the returning liquid mercury, then they pass through a superheater for the steam made, and then through an economizer for heating feed water, so that they arrive at the stack as cool as in a simple steam process with similar arrangements.

A paper entitled "The Emmet Mercury Vapor Process" has recently been contributed to the American Society of Mechanical Engineers, and from this the following description of the Hartford equipment is quoted:

THE HARTFORD INSTALLATION.

"The equipment at Hartford was designed to operate with 35-pound gauge pressure on the mercury boiler, to deliver about 1800 K.W. from the mercury turbine, and to make steam at 200-pound pressure with about 100 degrees of

* Address delivered Thursday, September 18, 1924, on the occasion of the celebration of the centenary of the founding of The Franklin Institute.

superheat. The furnace gases pass in order through the mercury boiler, a mercury-liquid heater, a steam superheater, and a feed-water heater. It would be more economical to substitute for the last-named device an air heater, since it would put this residuum of heat into the mercury instead of into the steam. The feed heat would then be accomplished by bleeding the steam turbine.

"The mercury vapor formed in the boiler passes through a governing and emergency valve to the turbine, the single wheel of which is overhung on the end of the generator shaft and operates in the condenser space. Two safety valves are arranged to bypass the vapor into the condenser if the governor causes its valve to close, so that the mercury vapor continues to be condensed and to make steam whether it is passing through the mercury turbine or not. The shaft passes through a packing between the generator and the turbine wheel and this is sealed by mercury vapor above atmospheric pressure. The outward leakage from this packing is sucked into a cooler where it is all condensed and returned to the system.

"The discharge from the turbine wheel is delivered directly against the condensing surface which consists of dead-ended tubes hanging vertically from a cylindrical steam and water drum, to which they are attached by rolling and also arc welding.

"The condenser shell and all the pipes and containers which carry mercury are put together by welding. From the condenser the liquefied mercury runs through a sump to the mercury heater and boiler by gravity.

"On the side of the condenser shell a large blowout diaphragm is provided which communicates to the stack and will give way if, through escape of steam or water or other cause, the pressure in the condenser should begin to rise unduly.

"The mercury boiler at Hartford is made up of fire tubes, the lower two-thirds of which are hexagonal with slightly convex faces. These are nested together like a honeycomb, and for each seven tubes a space is left for a duct which returns the circulating liquid. This liquid rises and the vapor forms in clearances between the tubes at the corners. The use of such tubes in a mercury boiler was proposed by Mr. B. P. Coulson, the author's assistant. The upper round part of the tubes acts as superheating surface and the vapor is delivered with a little superheat, which is desirable for the reason that it probably tends to prevent cutting of the turbine blades—of which there has been none at Hartford, although a slight amount was observed in former turbines.

"This equipment has been run experimentally for several months. Few troubles have been experienced and nothing of a serious nature. It has delivered power to the circuits for about 800 hours. The highest load carried has been 1500 kilowatts, and the load carried most of the time has been 1200 kilowatts. There has been some uncertainty as to the safe capacity of the boiler and, since experience with continued operation has been the most important need, it has been thought best to avoid risk of any possible serious trouble. The conditions of running cannot be considered commercial, but the results secured give a very good indication that commercial results are not difficult of attainment.

"As soon as certain boiler experiments now in progress are satisfactorily completed, it is proposed to build a new boiler of a different type for the existing Hartford installation. This boiler we propose to adapt for a pressure of 70-pound gauge, the design pressure of the present boiler being 35-pound gauge. We also intend to build a new three-stage turbine instead of the one-stage turbine now used. When these changes are made it is hoped that this installation will be representative of types which can be repeated indefinitely on a large scale and with such resultant economies as have been outlined in this paper."

If this process can be developed to a thoroughly workable condition, the economies obtainable are very high. With steam conditions equivalent to those in the best existing power stations, the gain in output per pound of fuel should be from 50 per cent to 60 per cent, and, as compared with the possibility of the very high-pressure installations contemplated, the gains should still be very large. The following table gives a comparison with expected results of the 50,000 K.W. high-pressure turbine unit which is to be installed at Chicago:

Heat Distribution per K.W. Output.

50,000 K.W. Turbine.

Expected Normal Monthly Operation.

Steam Pressure, 550-pounds Gauge; Temperature, 750 degrees F.; Reheat Pressure, 115-pounds absolute; Reheat Temperature, 700 degrees F.; Exhaust at 0.75 inches of heating absolute.

Compared with Mercury Steam Combination.

Mercury generating unit having an efficiency of 70 per cent and operating at 70-pound Gauge pressure; steam turbine being the same with same conditions but without reheating.

	Steam Alone		Mercury and Steam
Heat from fuel:	**B.T.U.**	**Per cent**	**B. T. U.**
Heat to normal boilers	14,004	93.4	
Heat to reheater	996	6.6	
	15,000	100.0	11,000
Heat from turbine returned to boilers by heaters	2320		
Heat distribution:			
Banked fire and standby losses	1800	12.0	1305
Stack loss	1443	9.6	1046
Other boiler losses	812	5.4	585
Auxiliary power	670	4.5	487
Net heat to steam jets, etc.	35	0.2	21
Heat to circulating water	6649	44.4	3983
Generator losses	178	1.2	103
Electrical energy from generator	3413	22.7	1992
		100.0	
Mercury generator losses			57
Electrical energy from mercury generator			1421
Total electrical energy 1 k. w. hour B. T. U.			3413

In these figures the auxiliary load has been taken as proportionate to the fuel burned, which assumption is unfavorable to the mercury process, since the load of circulating air feed and hot well pumps are all proportionate to the steam load and not to the fuel burned. The mercury apparatus adds no auxiliary but an air pump which takes very little power.

It should here be observed that the reheating of steam which is important to economy in the steam cycle, and which involves a great deal of expense and difficulty, is not required in the mercury steam combination.

From this table, it will appear that the mercury steam combination should give a gain in output per pound of fuel of 36 per cent over this very advanced steam application. In this comparison, the figures bear a positive relation to each other and there can be no appreciable error unless it be in the assumption as to the efficiency of the mercury turbine which would seem to be conservative.—"Journal of the Franklin Institute."

BRICKWORK OF FURNACES OF OIL-FIRED WATER-TUBE BOILERS.

A Correspondent Discusses Some Points in Connection With the Care and Maintenance of the Furnace Lining of Water-Tube Boilers.

The oil-fired water-tube boiler has been in use in naval vessels for many years, but it is only recently that similar installations have been fitted in certain vessels of the mercantile marine. The incessant demand for reduction of machinery weight in relation to the power developed would point to an extension of the system in commercial vessels of high speed, until such time as the development of the Diesel engine or internal-combustion turbine brings about the displacement of the boiler as the source of power in these vessels. In the maintenance in a state of efficiency of the external parts of an oil-fired water-tube boiler, the furnace brickwork claims a large share of the attention of the seagoing engineer, and is an important item in his boiler-room duties. Intelligent supervision is also necessary during the construction of the brickwork, and this applies with even greater force to the commercial vessel than to the warship.

WARSHIPS AND MERCHANT SHIPS.

During peace time, the latter, from the nature of her duties, spends more time in harbor than the merchant vessel, and even when at sea, except on occasions of full power trials, gun and torpedo exercises or Fleet maneuvers, wide ranges of relatively high cruising speeds can be maintained with only a portion of the boilers under steam. Thus the furnace brickwork of all boilers is under constant examination and repair, to keep it in readiness for full power steaming, and in the event of failure of the brickwork in a boiler at sea, the boiler can be cut out and another connected without loss of cruising speed. Further, a small working party skilled in repairs to brickwork is always available. The merchant vessel, however, has to make long passages with all boilers alight, and usually with short periods in intermediate ports, under conditions which often prevent that desirable "stitch in time" which is so necessary for continued efficiency being given to defects. Cutting out a boiler owing to defective brickwork involves a serious loss of speed, and, since opportunities for repair during passage are limited, it follows that the rebuilding of the boiler brickwork during the overhaul of the vessel is an operation in which the ships' officers should particularly interest themselves. The resistance of the bricks to the intense heat conditions existing in the furnace depends upon suitable selection from the different types available, but, apart from this, the stability of the completed wall is affected by vibration, the rolling and pitching of the vessel and the pulsations which sometimes occur in boilers burning oil fuel. On first heating a newly built wall, a certain amount of shrinkage takes place in the fireclay mixture forming the bonding between the courses, and the fireclay tends to become friable under the intense heat and is loosened by vibration.

THE YARROW BOILER.

In the large three-drum or Yarrow type of boiler the weight of brickwork in the back protecting wall is considerable. If too great a thickness of fireclay is used between the courses, its subsequent shrinkage will cause a loss of support for the bricks in a vertical direction, and the whole wall will tend to sag downwards, disturbing the brick-securing bolts. Should any of the latter be burnt away by reason of defective plugs, the whole wall becomes shaky, and may ultimately collapse in heavy weather, or the boiler casing may become seriously warped or burnt. It is most important that the bricks selected should be in good condition. As a rule, very little care is taken in the stowing and handling of fire bricks, and, as a consequence, a large number possess edges and corners chipped and broken down by rough usage, and are quite unsuitable for building into an oil-fired furnace. These defects may be temporarily covered over by pointing the finished brickwork, but service at sea quickly exposes them.

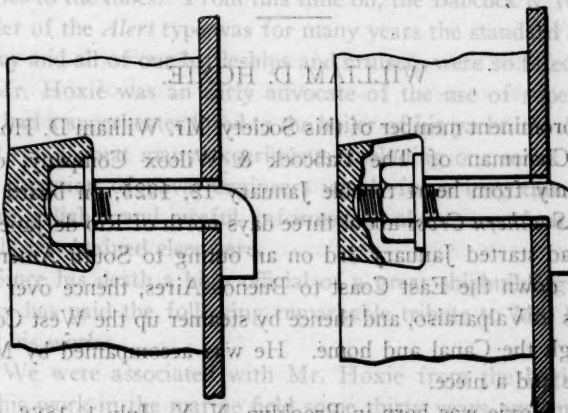
In erecting the brickwork of a new boiler, say of the Yarrow type, it is usual to build the back casing wall temporarily, so that the positions of the holes for the brick-securing bolts may be marked off for drilling in the inner casing plate. It is a common practice among bricklayers to place wooden battens, about ¼ inch thick, between the courses to represent the thickness of fireclay in the finished wall, and to space each brick in the course ¼ inch from its neighbor for the same reason. This method may be acceptable for a coal-fired boiler, but the heat conditions in an oil-fired furnace approach very nearly to those existing in a cupola or other melting furnace, and experience with the latter shows that the thickness of bonding material between the bricks should be kept to a minimum if the most satisfactory results are to be obtained.

CHOICE OF BRICKS.

Only undamaged bricks having sharp clean edges and corners should be selected, and in marking off the holes for the securing bolts the wall should be built temporarily with no allowance for an indiscriminate layer of fireclay between the courses or the bricks of a course. The holes having been drilled, the whole surface of the back casing plate, and also the foundation support of the wall, should be given a good coat of stiff clay wash. This thin coating of clay assists in forming an attachment between the bricks and the plate, as is shown in its everyday use in the foundry with core irons, hook bolts, and the insides of moulding boxes. A large bucket should be filled with a stiff mixture of fireclay and fine silica sand of about the consistency of porridge, and each brick should be dipped bodily into the mixture and then tapped into its position with a wooden mallet, and the securing bolt screwed up. In this manner the wall can be built up, and each brick will have, and will retain, the full support of those below, and any slight inequalities between the bricks will be closed by the fireclay mixture, the surplus of which should be well pressed out under light blows of the mallet, until practically brick-to-brick contact is made. A wall so built will require no pointing, which is useless under oil-fuel conditions, and provided good bricks are selected, it will present a fair and smooth surface to the flame.

The efficient protection of the ends of the securing bolts and their nuts is of great importance, and does not always receive sufficient attention. It is not unusual to see a bricklayer closing the bolt holes with portions of fireclay taken up on a trowel, thus leaving an air pocket in the recess, and providing indifferent plugs, which either fall out or are blown out on the first occasion of steaming, exposing the bolts to the flame. The tapered recesses and bolt ends should be given a coat of stiff clay wash, and the plugs should be kneaded and tamped into place with a small rammer, care being taken to

fill the hole completely and leave no air space, and the plug should be finished off slightly proud to the face of the brick after the fashion of a flush rivet. Care should be taken that the bolt ends do not project beyond the nuts, so that the maximum thickness of cover may be obtained to protect the bolt. The results obtained under the different circumstances described above are clearly shown in the sketches reproduced below. A good mixture for plug-



Correct (left) and Incorrect (right) Methods of Filling in Bolt Holes with Fireclay.

ging the bolt holes consists of old burnt brick ground up with about 30 per cent ganister, and its shrinkage may be reduced by working into the mixture a small proportion of coal in a fairly fine state of division. It is always advisable to give new brickwork time to set and dry thoroughly, and steam should be raised for the first time very slowly, and at all times rapid heating and cooling of the brickwork should, if possible, be avoided.—"The Marine Engineer and Motorship Builder," April, 1925.

OBITUARY.

WILLIAM D. HOXIE.

A prominent member of this Society, Mr. William D. Hoxie, Vice-Chairman of The Babcock & Wilcox Company, died suddenly from heart trouble January 12, 1925, on board the S. S. *Southern Cross* about three days north of Rio de Janeiro. He had started January 3rd on an outing to South America, going down the East Coast to Buenos Aires, thence over the Andes to Valparaiso, and thence by steamer up the West Coast through the Canal and home. He was accompanied by Mrs. Hoxie and a niece.

Mr. Hoxie was born in Brooklyn, N. Y., July 1, 1866, and received his early education in the public schools of that city. He was a born mechanic and engineer, so that, at the completion of his school course, he entered Stevens Institute of Technology, from which he graduated with credit in 1889, with the degree of Mechanical Engineer. The same year he became connected with The Babcock & Wilcox Company and all his active life thereafter was spent in the service of that Company.

Due largely to his remarkable energy and activity, the early installations of the Babcock & Wilcox boiler were made on board a number of merchant vessels, and in 1896 the first installations for the Navy were made in two little gunboats, the *Marietta* and *Annapolis*, and in the cruiser *Chicago*, followed by a set of boilers for the cruiser *Atlanta* in 1897.

Experience with the boiler as then designed led Mr. Hoxie to study possible improvements, and in 1899 the first Hoxie boilers were built for the U. S. S. *Alert*. This boiler was his

invention and the patents are in his name. It became the standard type of Babcock & Wilcox Marine Boiler, with the essential features of the drum in front, the increase of furnace volume towards the back of the boiler and the baffling at right angles to the tubes. From this time on, the Babcock & Wilcox boiler of the *Alert* type was for many years the standard in the Navy and all of our battleships and cruisers were so fitted.

Mr. Hoxie was an early advocate of the use of superheat. He had a superheater fitted to the boiler of his yacht, the *Idalia*, and ran a great many experiments, including one series under the direction of naval engineers which for a long time gave more reliable and useful information about superheat than could be obtained elsewhere.

Since his death a high official of a great shipbuilding company has paid the following remarkable tribute to Mr. Hoxie and his work:

"We were associated with Mr. Hoxie from the beginning of his work in the marine field some thirty years ago and we, probably more than any people outside of his own organization, know the difficulties he overcame in the early stages of this work and the great accomplishments he achieved for the U. S. Navy. I look upon him as one of the great engineering benefactors of our modern Navy and the soundness of his engineering is well proven by its unequalled success up to the present time.

"In fact, the only engineering of the Navy that was designed some thirty years ago and still survives is the work that he did. This work has not been replaced by better and more economical engineering as has been the case with everything else. The changes from coal to oil only prove the soundness of his work. His death is a great loss to the profession, as well as a great personal loss to all his acquaintances."

He became Vice-President of The Babcock & Wilcox Company in 1897. He held this position until 1919 when he succeeded Mr. Edward H. Wells as President when the latter became Chairman of the Board of Directors.

He had wonderful personal charm and amiability and was what is now often called "a great mixer." Everyone who came in contact with him was attracted to him and those who had the privilege became very warm and devoted friends, among these favored ones were many of the older members of this Society.

Mr. Hoxie was a Trustee of Stevens Institute of Technology, of Webb Institute of Naval Architecture, and of the Wilcox Memorial Library of Westerly, R. I. He was a member of the Engineers, N. Y. Yacht and Lawyers Clubs of New York City and of the Army and Navy Club of Washington, D. C. He was also a member of The American Society of Mechanical Engineers, the Society of Naval Architects and Marine Engineers and the Chamber of Commerce of the State of New York.

BOOK REVIEW.

THE STORY OF THE SEAMAN. BY JOHN FORSYTH MEIGS, LATE UNITED STATES NAVY: 2 VOLS., J. B. LIPPINCOTT CO.

It is a virtual impossibility to do justice to this monumental work in the short space permitted here. The story of the seaman, from earliest times, is placed before the reader with a minuteness of detail that raises the work to the dignity of a standard of reference. There is wealth both of illustration, and of reference notes to authorities cited, and consulted.

There is shown, step by step, the perfection of the seaman's art, commercial and military. If any deduction is to be made it is, in the light of cold reason and logic, that the sea is the road to national wealth and prosperity, and that the merchant and naval seaman are inseparable companions on that road.

It is probable that the most untimely death of the author prevented the presentation of the work in a smooth style worthy of its importance and magnitude. As published it shows a lack of careful proofreading, and even the punctuation leaves something to be desired, in the interest of clearness, at times giving the appearance of rough notes. These defects, it is to be hoped, will be corrected in subsequent editions. As it stands, however, it is a book that everyone interested in the sea will read with intense interest, and value as a permanent addition to his library.—G. B. V.

ASSOCIATION NOTES.

The following members have joined the Society since the publication of the last JOURNAL:

NAVAL MEMBERS.

Beaver, Lawrence Kirk, Lieutenant, U. S. Navy.

Falk, Walter S., Lieutenant, U. S. Navy.

Harwood, C. W., Ensign, U. S. Coast Guard.

CIVIL MEMBERS.

Bassett, W. B., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Carrick, J. J., Lieutenant Commander, U. S. N. R. F., 1323 Allison St., Chicago, Ill.

Clark, Everett F., Westinghouse Electric & Mfg. Co., 165 Broadway, New York City.

Dickinson, E. D., General Electric Company, West Lynn, Mass.

Fliedner, Carlyle S., Aeronautical Engine Laboratory, Naval Aircraft Factory, Philadelphia, Pa.

Foebel, G. H., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Hyler, A. M., 3006 17th St., N. E., Washington, D. C.

Miller, Spencer, 217 Turrell Avenue, South Orange, N. J.

Orr, Fred B., Lieutenant, U. S. N. R. F., 72 West Adams St., Chicago, Ill.

Sells, E. F., 302 Hibbs Building, Washington, D. C.

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